MOODY'S
INVESTORS SERVICE

SECTOR IN-DEPTH
28 November 2017

Rate this Research


Contacts

| | |
|---|---|
| Kelli Okuji<br>*Associate Analyst*<br>kelli.okuji@moodys.com | +1.415.274.1729 |
| Michael Wertz<br>*VP-Senior Analyst*<br>michael.wertz@moodys.com | +1.212.553.3830 |
| Kenneth Kurtz<br>*Senior Vice President*<br>kenneth.kurtz@moodys.com | +1.415.274.1737 |
| Leonard Jones<br>*MD-Public Finance*<br>leonard.jones@moodys.com | +1.212.553.3806 |

CLIENT SERVICES

| | |
|---|---|
| Americas | 1-212-553-1653 |
| Asia Pacific | 852-3551-3077 |
| Japan | 81-3-5408-4100 |
| EMEA | 44-20-7772-5454 |


Environmental risks

# Evaluating the impact of climate change on US state and local issuers

In coming years, climate change is forecast to result in a higher frequency and severity of extreme weather events, in turn heightening US exposure and vulnerability to economic loss across industries and geographic regions. This piece discusses how we assess the credit impact of these risks on US state and local issuers.

» **Global climate change is forecast to increase the US' exposure and vulnerability to a range of factors such as severe heat, changes in precipitation patterns and rising sea levels.** These changes are projected to drive an increased frequency of extreme weather occurrences, or climate shocks, including heat waves, droughts, nuisance flooding, wildfire and more damaging coastal storm surges. If federal, state and local governments do not adapt, these risks are forecast to become more frequent and severe over time. However, we anticipate that some level of adaptation and mitigation strategies will be adopted to lessen these impacts.

» **The negative economic effects of climate change vary by region.** Although climate change is certain to have economic impacts in the future, projections of costs are imprecise. The primary quantifiable impacts are damage to coastal property as a result of floods and rising sea levels, changes in agricultural production, lower labor productivity, health impacts and increased energy use. Changes in environmental policy and adaptive mitigation strategies will likely reduce these costs.

» **Credit risks resulting from climate change are embedded in our existing approach to analyzing the key credit factors in our methodologies.** Our analysis of economic strength and diversity, which signals the speed with which an economy may recover, captures climate-driven credit risks such as economic disruption, physical damage, health and public safety, and population displacement. Fiscal strength, access to liquidity and levers to raise additional revenue are also key to our assessment of climate risks as is evaluating asset management and governance. This provides the basis for our view of states' credit resiliency to climate change, and is the framework for evaluating the credit risk to local government issuers.

» **Local, state and federal tools for both immediate response and long-term recovery enhance resilience to the physical and economic impact of extreme weather events.** US municipal issuers benefit from local, state and federal processes to help areas affected by climate shock manage the immediate physical impacts of extreme weather. Issuers also benefit from a variety of resources to expedite the long-term recovery of their economic base.

## Incremental climate trends exacerbate extreme climate shocks

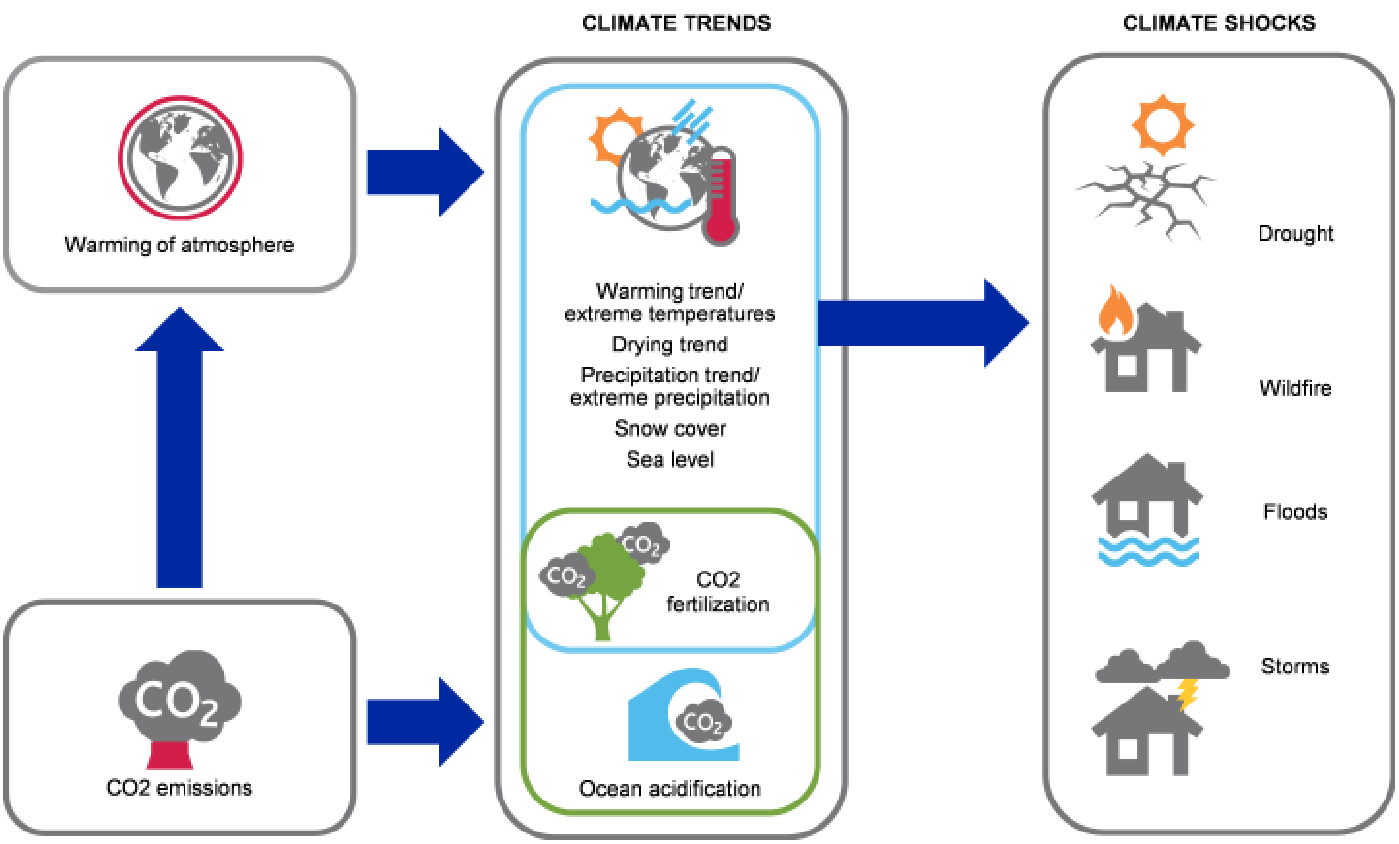
We distinguish between the long-term shift in the average state of the climate, known as climate trends, and climate shocks, or extreme weather events exacerbated by climate trend. We define climate trend and climate shock as follows:

**Climate trend**: Reflects gradual changes in the climate over multiple decades with little visible change from one year to the next, including incremental increases in average annual temperatures and a reduction in cold weather extremes. Changes in climate gradually increase sea levels, create more extreme precipitation patterns and produce more heat-driven weather extremes.

**Climate shock**: Refers to extreme weather events such as droughts, floods, wildfire and heat waves that are forecast to increase in frequency and intensity over time due to changing climate.

Climate trends are distinct from climate shocks, but they are interconnected (see Exhibit 1).

Exhibit 1
**Climate trends lead to climate shock**




*Source: Moody's Investors Service*

As climate change is incremental over a very long period of time, its impact on credit is difficult to determine. Nonetheless, changing climate trends can create credit risk at a tipping point that does not qualify as a climate shock as described above. For example, gradually increasing sea levels and acidification can contaminate agricultural land, erode soil and damage fisheries without causing a storm surge or massive storm that would be categorized as a climate shock. Our credit analysis considers the effects of climate change when we believe a meaningful credit impact is highly likely to occur and not be mitigated by issuer actions, even if this is a number of years in the future.

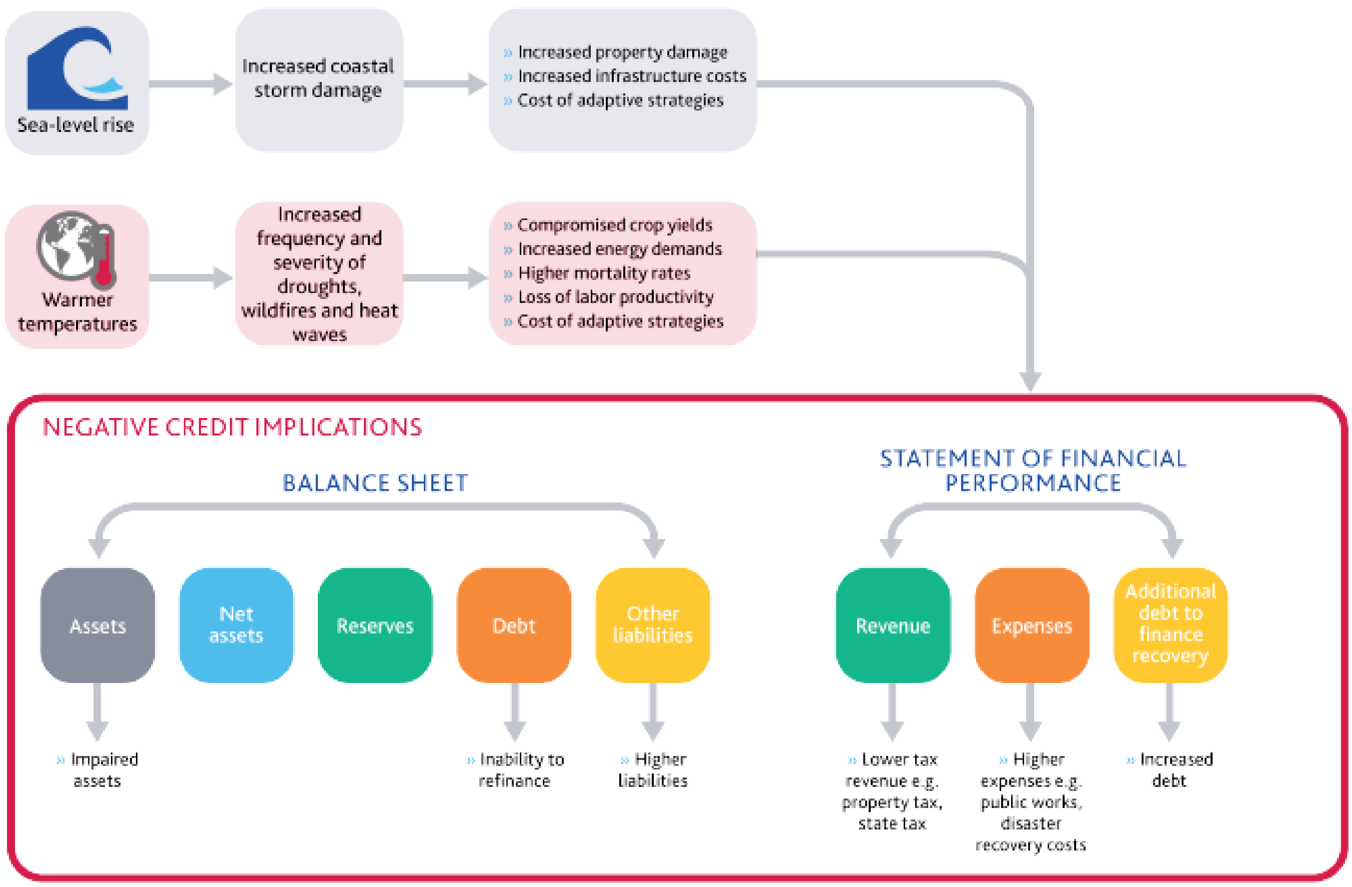
Climate shocks or extreme weather events have sharp, immediate and observable impacts on an issuer's infrastructure, economy and revenue base, and environment. As such, we factor these impacts into our analysis of an issuer's economy, fiscal position and capital infrastructure, as well as management's ability to marshal resources and implement strategies to drive recovery. The interplay between an issuer's exposure to climate shocks and its resilience to this vulnerability is an increasingly important part of our credit analysis, and one that will take on even greater significance as climate change continues.

## How climate risk transmits to credit risk

Long-term climate changes, including rising global temperatures and sea levels, are forecast to drive increased extreme weather patterns and other vulnerabilities like flooding that might put negative credit pressure on US issuers. Extreme weather patterns exacerbated by changing climate trends include higher rates of coastal storm damage and more frequent and severe droughts, wildfires and heat waves. In addition to loss of life and threats to public health and safety, these events present a multitude of challenges in the form of compromised crop yields, economic disruption, damage to physical infrastructure, increased energy demand, recovery and restoration costs, and the cost of adaptive strategies for prevention or impact mitigation. These challenges can result in lower revenue, increased expense, impaired assets, higher liabilities and increased debt, among other effects. In addition to damage to infrastructure, the City of New Orleans' (A3 stable) revenue declined significantly and a material proportion of its population was displaced by Hurricane Katrina.

Exhibit 2

**Example of how climate risk can be transmitted to credit risk**




*Source: Moody's Investors Service*

## Global climate change increasing US' vulnerability to factors such as severe heat, rising sea levels

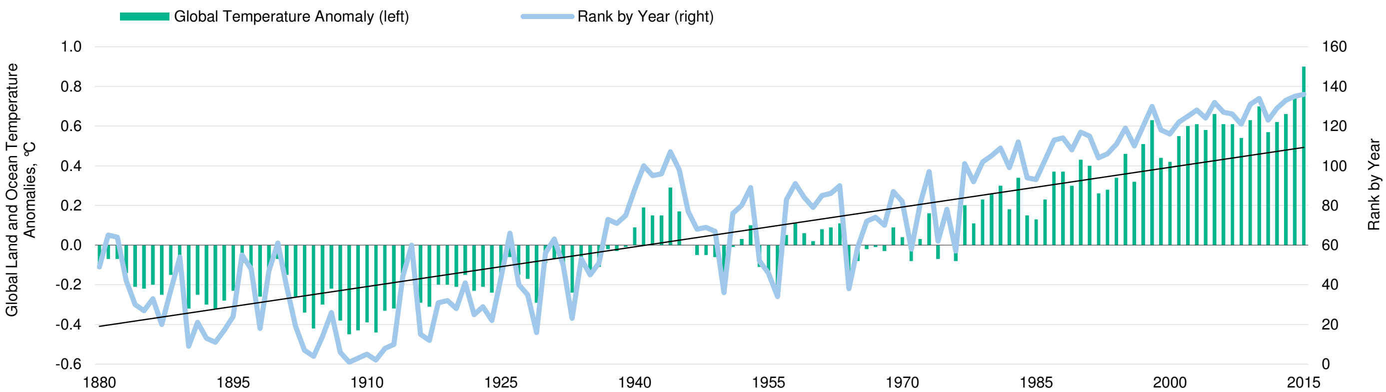
### Rising temperatures

According to the US National Climate Assessment, the average temperature over the US has risen by 1.3 degrees to 1.9 degrees Fahrenheit since 1895, with the majority of the increase having occurred since 1970. The increase in US temperatures is consistent with the global warming trend, which incorporates an accelerated increase in average temperatures over the last three decades, as Exhibit 3 shows.

Exhibit 3

**Global average temperatures continue to rise**

**Global land and ocean temperature anomalies, 1880-2015**

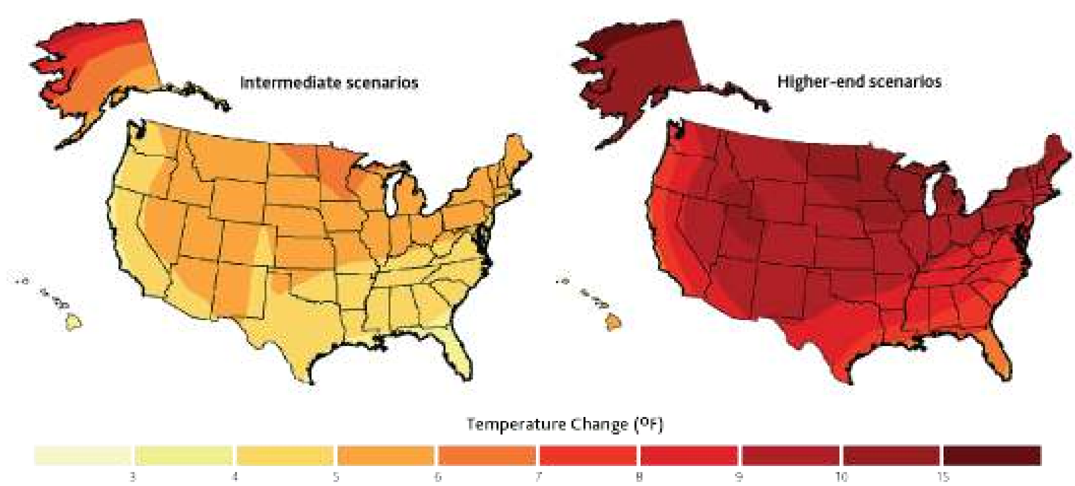



*Source: National Oceanic and Atmospheric Administration, National Centers for Environmental Information*

Scientists estimate that, at the current level of global $CO_2$ emissions, the rate of increase in average temperatures for the US will likely exceed the global rate absent additional adaptation or mitigation strategies. In this scenario, as Exhibit 4 shows, average US temperatures will likely increase by more than 8 degrees Fahrenheit by 2100 (Representative Concentration Pathway (RCP) 8.5).

Exhibit 4

**US temperatures are forecast to increase by varying amounts, depending on future emissions levels**



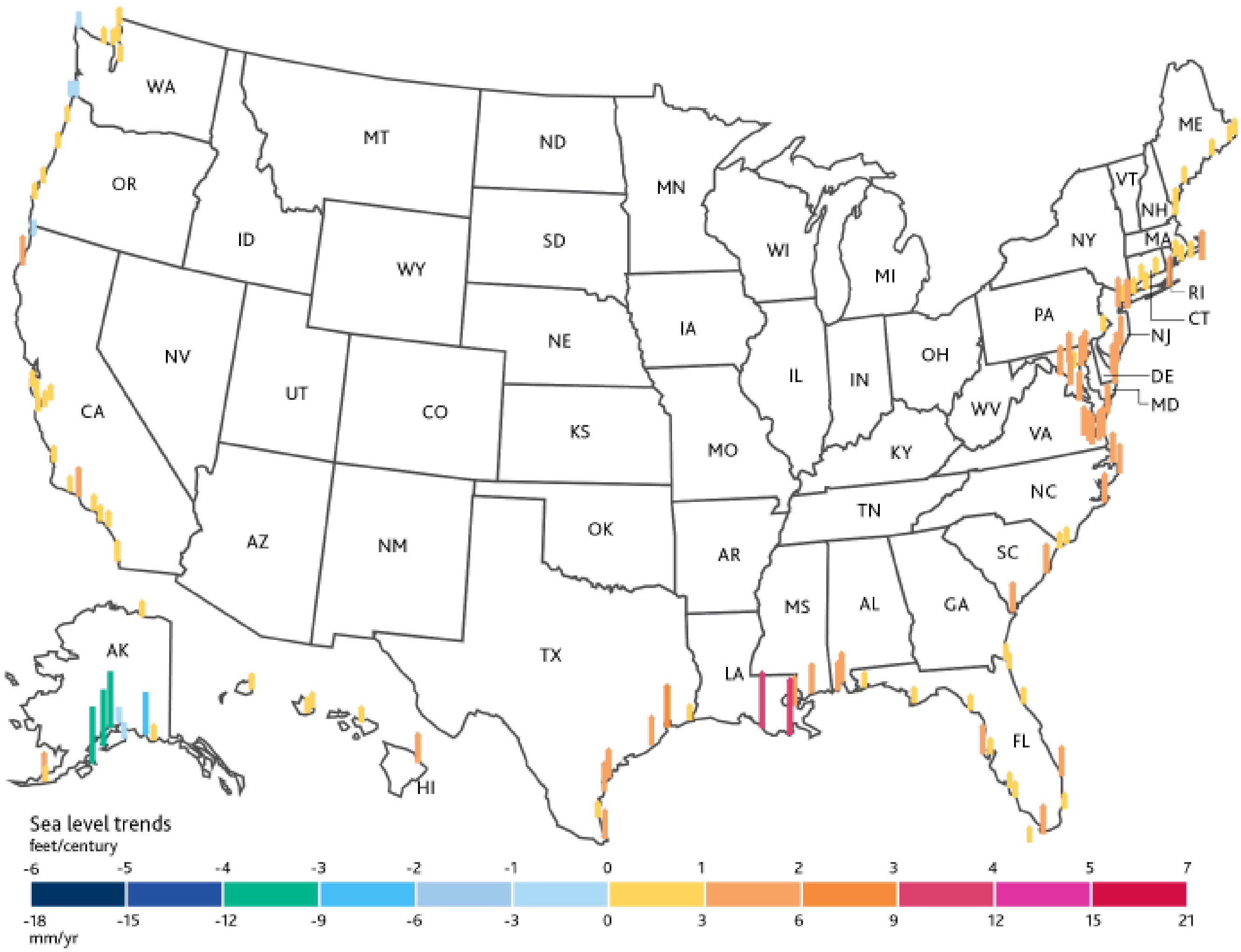

*Source: National Climate Assessment*

In 2015, 195 nations adopted the Paris climate agreement, which seeks to limit global emissions and reduce the rate of temperature increase. If the agreement is not effectively implemented and emissions remain close to current levels, scientists believe that the US would likely see a significant increase in extremely hot days.

## Sea levels increase

» The National Ocean Service forecasts that the global average sea level rise will continue. In 2014, the global average sea level rise was about 2.6 inches above the 1993 average [1]. Virtually the whole of the US coast has experienced rising sea levels, to varying degrees, with the Gulf Coast most acutely affected.

Exhibit 5
**Sea levels have risen in coastal areas of the US**



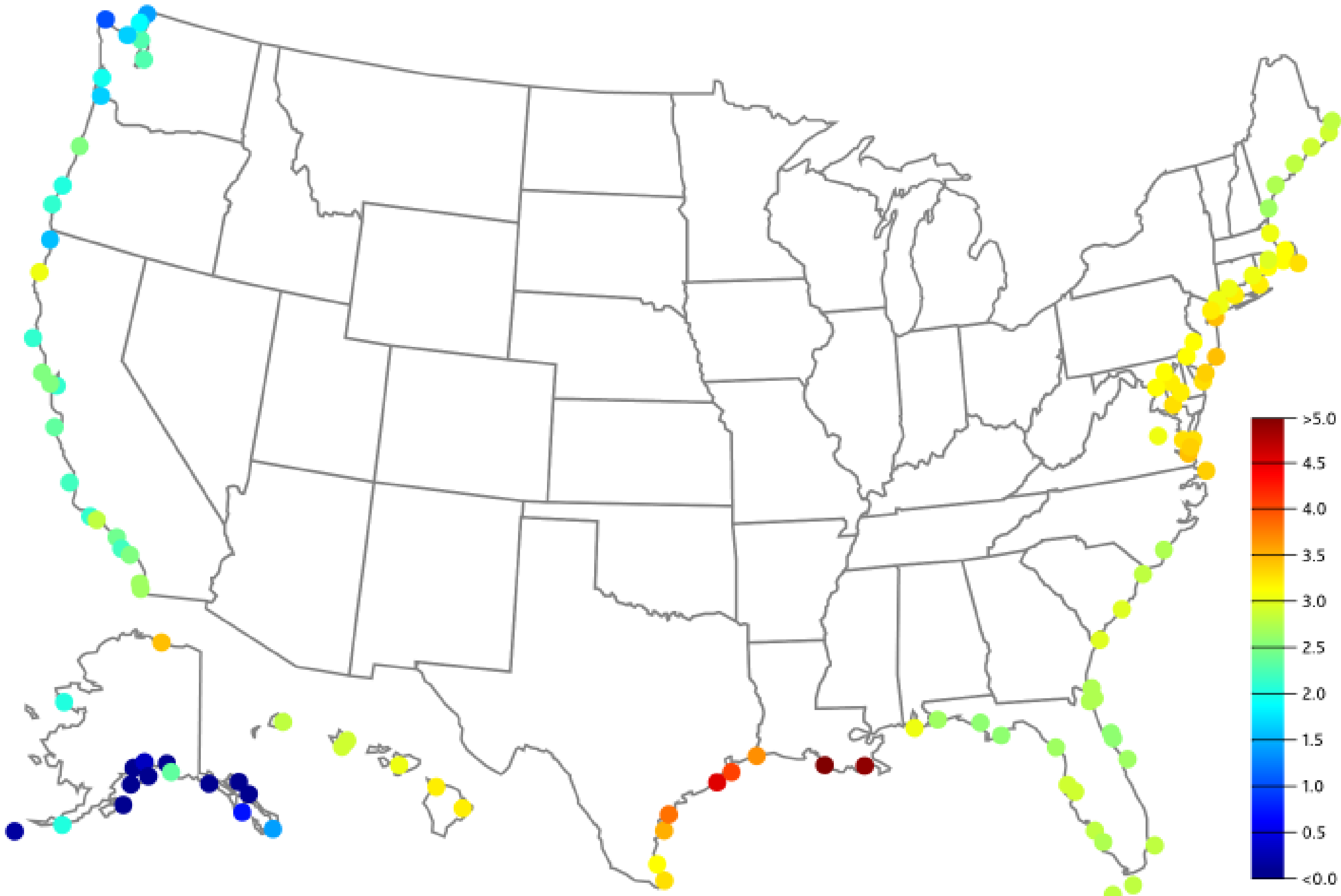

*Source: National Oceanic and Atmospheric Administration*

In the intermediate scenarios of National Oceanic and Atmospheric Administration scientists, global mean sea levels could rise by an estimated three feet by 2100. In the US, both the Pacific and Atlantic coasts would likely see even faster rates of regional sea level rise.

Exhibit 6

**US sea levels are forecast to continue to rise through 2100, with the Gulf Coast most acutely affected**

**Feet of sea level rise by 2100**



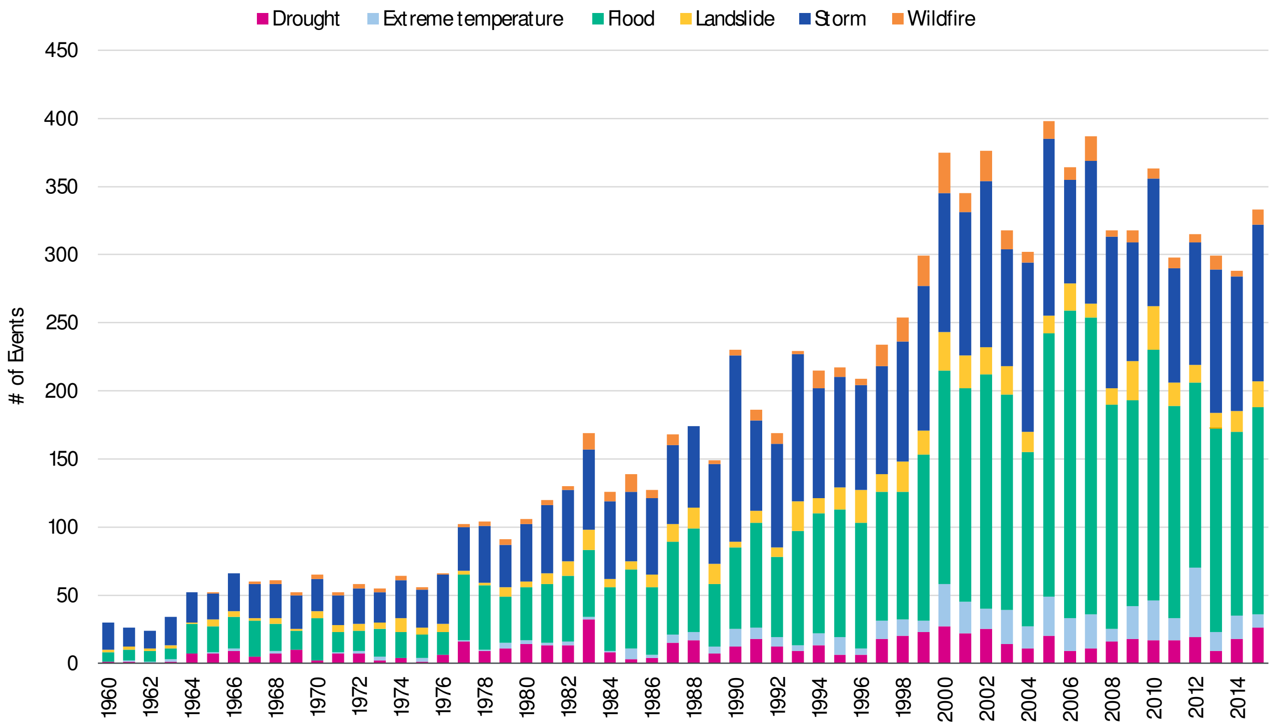

*Source: Economic Risks of Climate Change: An American Prospectus, by Trevor Houser, Solomon Hsiang, Robert Kopp, Kate Larsen et al (New York: Columbia University Press, 2015). Use by permission of Columbia University Press. Copyright ©2015 Solomon Hsiang, Robert Kopp and Rhodium Group.*

US sea levels are forecast to rise even if global emissions are reduced in accordance with the Paris agreement, though at a lower rate. The high degree of variability in projections for sea level increases means that there are plausible, albeit unlikely, scenarios in which the level of sea level rise could be as high as eight feet[2].

## Climate change expected to drive more intense impacts from severe weather events such as drought and heat waves

The National Climate Assessment (NCA) indicates that climate shocks such as heat waves and droughts have increased in recent years and that climate change has increased their probability. Although future projections of climate shocks are uncertain, the frequency of natural disasters increased materially before a recent plateau, as Exhibit 7 shows.

Exhibit 7
**Natural disasters are becoming more frequent**




*Source: Moody's Investors Service, EM-DAT International Disaster Database*

The NCA forecasts that droughts will intensify as a result of higher temperatures and lower precipitation in some areas. This would fuel both hydrological droughts as a result of reduced water in the ground, reservoirs and rivers, and meteorological droughts stemming from insufficient precipitation. Higher temperatures are expected to also drive more intense and sustained heat waves, as well as a greater number of wildfires.

Expected higher sea levels mean that destructive storm surges are forecast to push floodwaters further inland than they would otherwise reach. This would be particularly damaging for low-lying coastal communities that are susceptible to flooding. Even in the absence of increased precipitation, coastal areas could experience sharp increases in flooding due to higher sea levels. Independent of storm surges, rain-driven flooding events may also become more frequent and damaging.

While not as noticeable as a single catastrophic flood, more frequently recurring nuisance flooding could be increasingly costly over time. The cumulative effect of multiple nuisance floods causes substantial damage to roads, buildings and other infrastructure, on top of the costs of repeated stormwater mitigation.

## Economic effects of climate change vary by region and are expected to increase over time

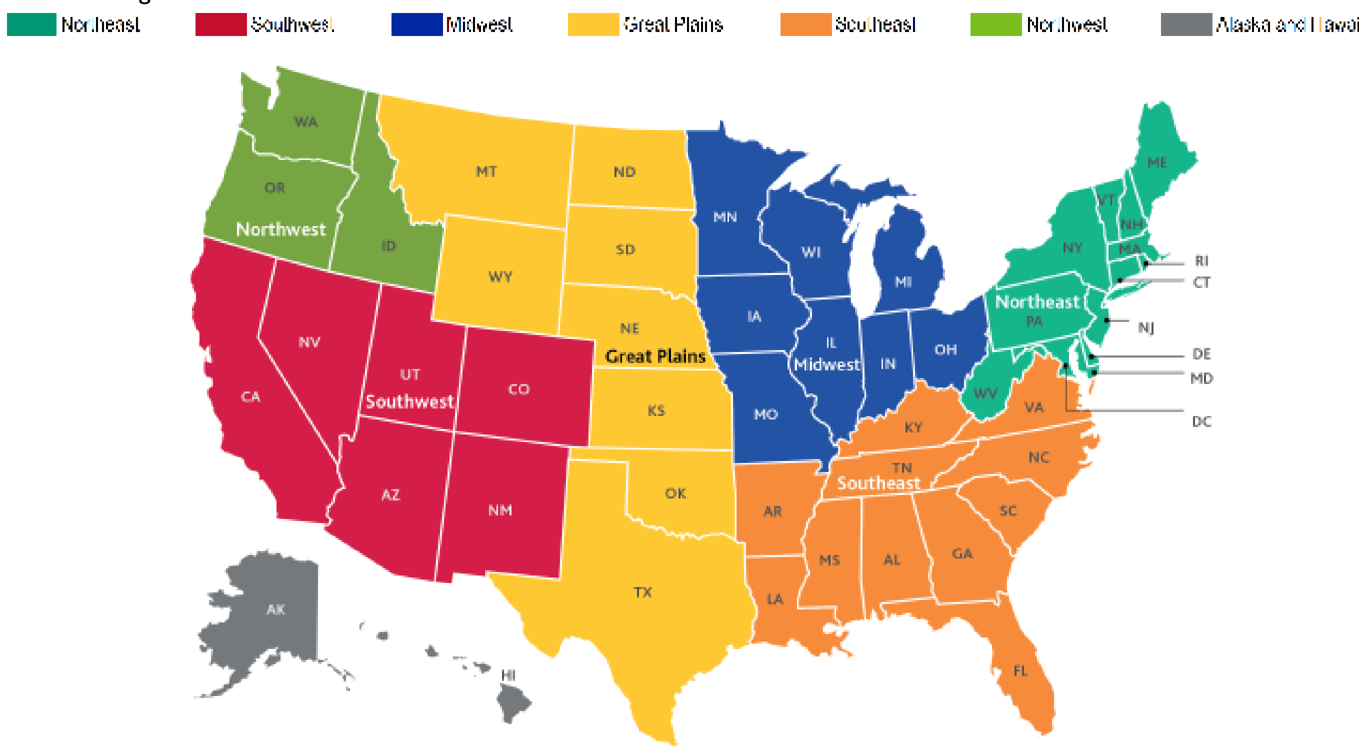
The expense of climate shock is expected to increase over time barring the implementation of effective mitigation strategies, which themselves carry some financial cost. While we anticipate that US issuers will adopt economic, environmental and infrastructure development practices that defray some of the worst impacts of future climate shocks, both the cost of adaptation and the level of effectiveness are highly variable.

The primary quantifiable US economic risk stemming from climate change consists of damage to coastal property due to rising sea levels and storm surge; damage to property due to non-coastal events such as droughts, wildfires, floods and severe storms; and changes in agricultural production, labor productivity and public health. The economic costs also include the costs of adaptation and mitigation measures. Adaptation measures are primarily infrastructure investments intended to prepare for the direct impact of climate change, including improvements to dams, levees and seawalls, and enhanced storm drainage systems. Mitigation measures are investments intended to reduce climate change itself, including conversion from carbon-based energy sources to renewable sources, and are likely to present an economic challenge in existing energy-producing states. However, we recognize that, due to the evolving nature of the science, there may be other risks that are less known or quantifiable, and which may have an even greater impact.

Economic exposure to the impact of climate change is not uniform across the country: differences in economy and geography drive variations in respect of regional economic impact. Below, we summarize the primary economic exposures of different regions and states. We have not identified exposure at the local level due to the limited availability of data at the county level and below.

Exhibit 8

**US climate regions**




*Source: National Climate Assessment*

## Northeast

Expected rising sea levels and their effect on coastal infrastructure represent the major impact in the Northeast. Additional impacts from climate change are forecast to include increased heat waves and risks to fisheries and agriculture. Approximately 88% of the Northeast's population lives in coastal counties which also account for 68% of the region's GDP. This concentration means that the economic effect of storm surges are forecast to be more damaging. On the current emissions pathway, average annual property losses from hurricanes and coastal storms are projected to increase by between $6 billion and $11 billion by 2100. Already increased sea levels exacerbated the storm surge of Hurricane Sandy in 2012. However, the reduced emissions pathway that the Paris agreement envisions, along with adaptive practices, may reduce economic loss stemming from coastal storms.

## Southeast

The Southeast is forecast to be among the US regions most affected by higher temperatures. On the current emissions pathway, increased temperatures are expected to reduce labor productivity and drive up heat-related mortalities over the course of the current century. Emissions consistent with the Paris agreement are still projected to increase heat-related mortalities, though such incidents could be significantly lower. Rising sea levels are also forecast to drive an increase in water damage to property and infrastructure as a result of storm surges or nuisance flooding, and could also damage coastal infrastructure. Major cities such as New Orleans are below sea level, while others such as Miami are vulnerable to inundation.

### Midwest

Impacts on agriculture are forecast to be among the most significant economic effects of climate change in the Midwest. In addition to estimated temperature increases, the region could become susceptible to more frequent extreme weather events. The NCA projects that over the course of the century, climate change will likely drive down agricultural productivity if there is no change in course and temperatures continue to increase. The impact on agricultural productivity could be reduced in a lower emissions scenario. We recognize that the agriculture industry is adaptable to climate change and well suited to mitigate this risk by changing crop type and implementing other compensatory practices. However, the cost of adaptation is an uncertain expense borne by individual farms and communities. The region may also have to bear the costs of mitigation practices to offset more frequent heat waves and the impact these may have on mortality and labor productivity. A heatwave in Chicago in July 1995 killed 730 people[3].

### Great Plains

The Great Plains is forecast to be most affected by rising temperatures that put increasing strain on water supplies and energy and may also hinder development. Reduced water supplies would also be problematic for the region's highly productive energy sector, which generates power from oil, coal, wind and natural gas. Warmer temperatures may increase the intensity of hydrological droughts as water supplies become more susceptible to evaporation and increased competition for supply. This situation is exacerbated by projections that the rate of increased energy demand would be higher in this region than anywhere else in the country, as people become more reliant on air conditioning. Southern areas could also be confronted by damage to coastal infrastructure and threats to agricultural productivity which, like the Midwest, will require resources to implement adaption. The Texas Gulf Coast already experiences frequent tropical storms and hurricanes that will exacerbate storm surges and drive water further inland.

### Southwest

The already hot and dry Southwest is projected to become even more vulnerable to extreme heat, rising sea levels along the California coast, drought and wildfires. Increased temperatures would increase the length and severity of drought and economic threats to agriculture. This would affect states such as California, whose water supplies depend on mountain snowmelt that would become less abundant as winters become shorter, precipitation declines and reservoirs evaporate. These states would also become more prone to more frequent and intense droughts. The region's susceptibility to wildfire and higher energy demand would also increase significantly. In addition, the 1,350km California coast is exposed to rising sea levels that will aggravate storm surges and flooding.

### Northwest

Projected climate change impacts in the Northwest are more muted than in other parts of the country but still significant. Washington, Oregon and Idaho have vast forests that produce a substantial portion of the US' lumber supplies. Temperature increases and precipitation declines would cause forests to become more vulnerable to wildfires and insects whose numbers will be less affected by colder winters. Although the rise in sea levels is expected to be less pronounced than for other regions, the Northwest would be vulnerable to increased ocean acidification and erosion impacting the fishing industry.

### Alaska and Hawaii

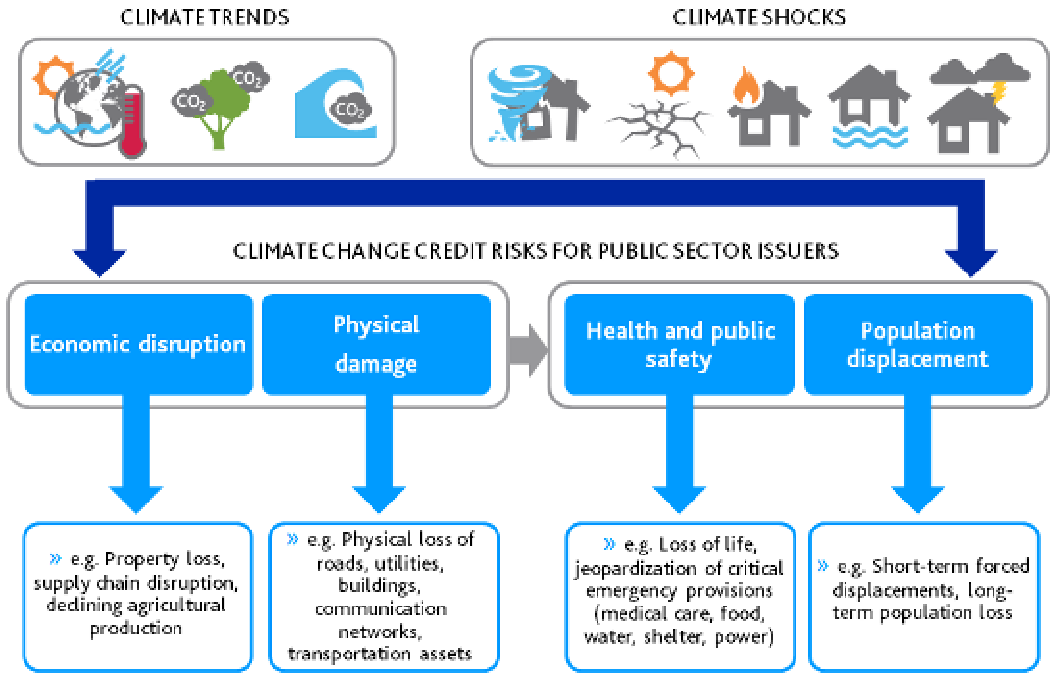
Scientists estimate that Alaska has been more affected by climate change than any other US state. Temperatures have risen at more than double the rate in the rest of the country. Warmer temperatures are causing glaciers, sea ice and animal habitats to deteriorate, and have had varying effects on sea levels. The state produces around half the US' domestic commercial fish supply: more temperate waters that increase ocean acidification could reduce this productivity. Climate change in Hawaii is forecast to accelerate sea level rise and increase water temperatures. This would drive ocean acidification and beach erosion, and could reduce the availability of freshwater as a result of saltwater intrusion.[4]

## Climate change credit risks are embedded in our approach to analyzing the key credit factors in our methodologies

Our rating methodologies for states, local governments and public utilities do not explicitly address climate change as a credit risk. However, the credit challenges that climate change poses are captured in our analysis of economic strength and diversity, capital asset management, fiscal strength and governance, among other credit factors. In addition, local governments that face a higher risk of climate shocks are specifically asked by analysts during the rating process about their preparedness for such shocks and their activities in respect of adapting to climate trends.

We identify the primary state and local issuer credit risks of climate change as:

Exhibit 9




*Source: Moody's Investors Service*

### Economic disruption

State and local economic output can decline due to immediate climate shock events or the impact of long-term changes in climate trends. Either of these developments can drive economic disorder as a result of property loss, disruption to supply chains, declining agricultural production and other impacts. For issuers, significant economic loss will weaken their revenue base while simultaneously confronting them with current or long-term costs for recovery. Other costs include the costs of adaptation and mitigation measures, increased infrastructure investment and higher insurance costs.

Extreme weather significantly disrupted the City of New Orleans' economy following Hurricane Katrina in 2005. In May 2005, our rating on the city's $496 million of unlimited general obligation tax debt was Baa1. We subsequently downgraded to Ba1, in large part due to the unprecedented disruption to the city's economy and revenue that Hurricane Katrina caused, as well as concerns over the city's ability to fund ongoing operations[5].

### Physical damage

Climate shock can result in the physical loss of roads, utilities, buildings, communications networks and transportation assets. Recognition of changes to long-term climate trends can also generate significant costs related to upgrading infrastructure to prevent future damage. The cost of repairing or replacing infrastructure can substantially add to an issuer's current capital expenses or long-term debt burden.

In February 2017, the spillway of the Lake Oroville Dam in California was compromised as a series of storms resulted in sufficient precipitation to cause the reservoir to overflow the dam. Although the dam did not collapse, the California Department of Water Resources (Aa1 stable) will bear the $275 million cost of repairing it.

### Health and public safety

In the wake of a climate shock, issuers are confronted not only with possible loss of life, but also the task of restoring sufficient levels of systems to protect public health and safety. The emergency provision of access to medical care, food, water, shelter and power can put significant and unanticipated stress on an issuer's budget and personnel.

## Population displacement

Climate shocks can result in short-term but immediate population displacement, as well as the risk of permanent population loss due to relocation. Long-term changes in climate trends may prompt steady migration that undermines local economies. The credit effect on state and local issuers that lose population includes unanticipated changes in the labor market, lower economic productivity and a reduced revenue base. Localities that gain an influx of new residents from either climate shocks or climate trends face a mix of uncertain credit implications including a broader labor and economic base, but also increased demand for public services and associated costs.

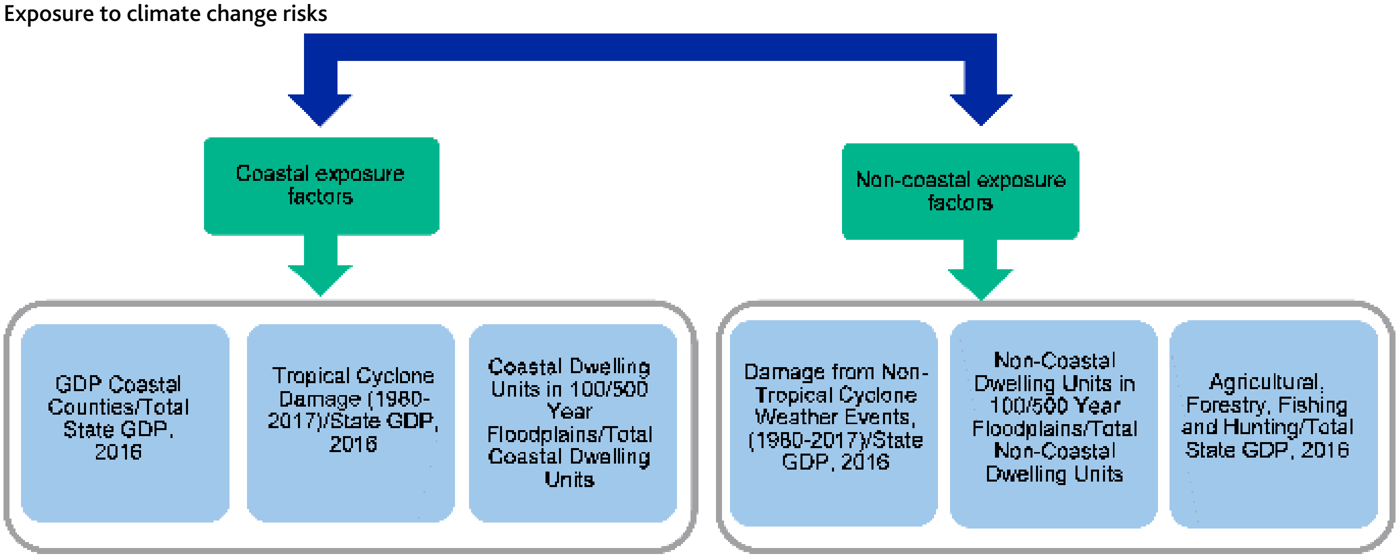
New Orleans' population in 2004 was estimated at approximately 455,000 people, while assessed valuation and total sales tax revenue were $16.7 billion and $150 million respectively. In 2006, following Hurricane Katrina, the population fell to 223,000, and assessed valuation and total sales tax revenue to $12.9 billion and $115 million respectively[6]. The city's population has never fully recovered. At the same time, the City of Houston (Aa3 negative ) experienced some economic benefit from absorbing approximately 150,000 evacuees following Hurricane Katrina. While the city estimated its initial costs for disaster-related expenditure at $165 million, it also anticipated that the Federal Emergency Management Agency (FEMA) and non-city sources would reimburse 100% of the costs [7].

## US states' exposure and overall susceptibility to climate change

In common with how the economic effects of climate change differ by geographic region, exposure to climate risks varies by state. In Exhibit 10, we present a sample of some of the metrics we use to assess the exposure and overall susceptibility of US states to the physical effects of climate change. We present six metrics, three of which focus on coastal risks – rising sea levels, the increased frequency and severity of tropical cyclones including hurricanes, and the combined effect of rising sea levels and coastal storms. The remaining three metrics focus on climate change risks other than rising sea levels and coast storms, including the increased frequency of higher temperatures, droughts, wildfires, non-coastal flooding, and severe storms including tornadoes. (See Appendix for details on the exposure metrics and their sources.)

Exhibit 10

**Exposure to climate change risks**




*Moody's Investors Service*

We also emphasize that many factors mitigate the physical exposure of US states, including economic resources, financial flexibility, governance strengths, the availability of FEMA funding for natural disasters, the redistributive impact of federal tax and social policies, and the establishment by some states of special reserve funds for hurricanes and other natural disasters. These mitigating factors are heavily weighted into our state ratings.

Exhibit 11
## US states' exposure to climate change varies

| | Exposure to Climate Change Risk | | | | | |
|---|---|---|---|---|---|---|
| | Coastal Exposure Factors | | | Non-Coastal Exposure Factors | | |
| State | GDP Coastal Counties/Total State GDP, 2016 | Tropical Cyclone Damage, 1980-2017/State GDP, 2016 | Coastal Dwelling Units in 100/500 Year Floodplains/Total Coastal Dwelling Units | Damage from Non-Tropical Cyclone Weather Events, 1980-2017/State GDP, 2016 | Non-Coastal Dwelling Units in 100/500 Year Floodplains/Total Non-Coastal Dwelling Units | Agricultural, Forestry, Fishing and Hunting/Total State GDP 2016 |
| AK | 85.9% | 0.0% | 3.2% | 3.2% | 3.3% | 1.1% |
| AL | 13.0% | 7.3% | 15.1% | 7.7% | 6.0% | 1.3% |
| AR | 0.0% | 0.3% | 0.0% | 9.8% | 9.9% | 2.8% |
| AZ | 0.0% | 0.0% | 0.0% | 2.0% | 61.4% | 0.7% |
| CA | 78.0% | 0.0% | 15.2% | 2.0% | 12.4% | 1.3% |
| CO | 0.0% | 0.0% | 0.0% | 5.7% | 3.2% | 0.7% |
| CT | 59.4% | 1.2% | 8.6% | 0.9% | 0.3% | 0.1% |
| DE | 100.0% | 0.9% | 10.0% | 2.0% | 0.0% | 0.8% |
| FL | 76.7% | 14.8% | 37.7% | 1.7% | 9.4% | 0.7% |
| GA | 5.4% | 1.1% | 43.3% | 2.7% | 4.8% | 0.8% |
| HI | 100.0% | 6.5% | 11.7% | 0.0% | 0.0% | 0.5% |
| IA | 0.0% | 0.0% | 0.0% | 17.9% | 3.7% | 5.6% |
| ID | 0.0% | 0.0% | 0.0% | 6.7% | 6.8% | 5.1% |
| IL | 0.0% | 0.1% | 0.0% | 3.7% | 3.2% | 0.8% |
| IN | 0.0% | 0.2% | 0.0% | 5.2% | 5.9% | 1.4% |
| KS | 0.0% | 0.0% | 0.0% | 15.2% | 7.8% | 2.9% |
| KY | 0.0% | 0.5% | 0.0% | 7.0% | 5.5% | 1.2% |
| LA | 52.8% | 60.4% | 34.1% | 11.5% | 12.1% | 0.7% |
| MA | 82.4% | 0.5% | 10.6% | 0.7% | 3.9% | 0.2% |
| MD | 69.2% | 1.2% | 4.4% | 1.5% | 0.7% | 0.2% |
| ME | 59.1% | 0.2% | 8.3% | 2.1% | 2.1% | 1.3% |
| MI | 0.0% | 0.0% | 0.0% | 1.2% | 4.1% | 0.7% |
| MN | 0.0% | 0.0% | 0.0% | 5.4% | 3.1% | 1.9% |
| MO | 0.0% | 0.1% | 0.0% | 11.4% | 3.6% | 1.3% |
| MS | 14.6% | 43.8% | 37.7% | 14.9% | 10.2% | 2.5% |
| MT | 0.0% | 0.0% | 0.0% | 22.6% | 5.5% | 3.9% |
| NC | 10.5% | 5.5% | 26.2% | 2.6% | 3.2% | 1.0% |
| ND | 0.0% | 0.0% | 0.0% | 41.9% | 19.6% | 4.6% |
| NE | 0.0% | 0.0% | 0.0% | 14.7% | 8.8% | 6.5% |
| NH | 31.0% | 0.5% | 9.2% | 1.5% | 6.5% | 0.3% |
| NJ | 78.8% | 5.7% | 11.6% | 1.2% | 2.0% | 0.1% |
| NM | 0.0% | 0.3% | 0.0% | 3.7% | 5.7% | 1.2% |
| NV | 0.0% | 0.0% | 0.0% | 1.3% | 11.0% | 0.2% |
| NY | 74.6% | 3.0% | 6.7% | 0.6% | 2.6% | 0.2% |
| OH | 0.0% | 0.4% | 0.0% | 2.0% | 4.1% | 0.6% |
| OK | 0.0% | 0.0% | 0.0% | 13.6% | 8.2% | 1.5% |
| OR | 12.2% | 0.0% | 11.8% | 2.3% | 5.1% | 1.7% |
| PA | 15.8% | 0.9% | 2.5% | 1.1% | 4.4% | 0.5% |
| RI | 100.0% | 1.7% | 9.4% | 1.5% | 0.0% | 0.2% |
| SC | 29.7% | 7.4% | 0.9% | 4.4% | 0.3% | 0.5% |
| SD | 0.0% | 0.0% | 0.0% | 23.3% | 7.0% | 8.0% |
| TN | 0.0% | 0.1% | 0.0% | 6.6% | 4.3% | 0.5% |
| TX | 31.1% | 3.6% | 26.4% | 4.5% | 6.2% | 0.7% |
| UT | 0.0% | 0.0% | 0.0% | 1.3% | 3.6% | 0.5% |
| VA | 65.6% | 1.4% | 8.4% | 1.4% | 3.5% | 0.3% |
| VT | 0.0% | 3.0% | 0.0% | 3.1% | 4.8% | 1.2% |
| WA | 76.9% | 0.0% | 4.5% | 0.9% | 0.9% | 1.6% |
| WI | 0.0% | 0.0% | 0.0% | 3.5% | 5.3% | 1.7% |
| WV | 0.0% | 0.9% | 0.0% | 5.2% | 11.1% | 0.4% |
| WY | 0.0% | 0.0% | 0.0% | 7.8% | 4.6% | 1.5% |

*Source: Moody's Investors Service*

Although comparable data for the each of the five self-governing US territories is unavailable, we incorporate the risk of climate change into our ratings for the territories in the same way as we do for other governments. Due to their geography, exposure to climate change risk for some of the territories is elevated and generally higher than for the continental US. Territories also tend to have less resilience to these risks, given their smaller, less diversified economies and fewer local financial resources relative to a US state. The territories receive assistance from FEMA just as governments on the mainland do, but it may not be delivered as efficiently as for a state or local government. As such, for the US territories compared with the 50 US states, we see greater climate change exposure, slower implementation of long-term adaption and mitigation strategies, and greater challenges for post-shock recovery.

## Analysis of key credit factors captures local government resilience

The resilience of local government issuers to credit risks originating from long-term changes in climate trends and immediate climate shocks is also a function of economic strength, fiscal flexibility, debt affordability, and governmental policies and planning. We address each of these factors as we apply our rating methodologies to analyzing an issuer's credit profile. For example, our US Local Government General Obligation Debt Rating methodology incorporates a weighted analysis of the broad rating factors that inform the assignment of a general obligation bond credit rating. This includes analysis of various sub-factors related to the issuer's economy, finances, management and debt. Exhibit 12 illustrates how consideration of climate risks is embedded in our approach and accounted for in our analysis.

Exhibit 12

**Credit impact of climate risks captured in Local Government General Obligation methodology**

| Broad Rating Factors | Factor Weighting | Rating Sub-Factors | Sub-Factor Weighting | Impact of Climate Risks |
|---|---|---|---|---|
| Economy/Tax Base | 30% | Tax Base Size | 10% | Climate shocks may weaken economic output and tax base valuation and reduce the issuer's revenue base. Issuers with economies concentrated in sectors exposed to climate risks face higher credit vulnerability. Small economies that can be disproportionately impacted by climate events are at a heightened risk. Issuers with head room between their current tax rate and the legal tax rate limit have additional flexibility to raise taxes/ revenues as needed to provide additional resources. Issuers with large, diverse economies will suffer lower credit impacts from climate risks. |
| | | Full Value Per Capita | 10% | |
| | | Wealth (median family income) | 10% | |
| Finances | 30% | Fund Balance (% of revenues) | 10% | Fiscal flexibility can be challenged by unanticipated emergency response costs, infrastructure repair costs, the loss of revenue or the cost of adaptive strategies. Issuers with healthy overall financial positions and strong liquidity are best positioned to service these risks with minimal credit impacts. |
| | | Fund Balance Trend (5-year change) | 5% | |
| | | Cash Balance (% of revenues) | 10% | |
| | | Cash Balance Trend (5-year change) | 5% | |
| Management | 20% | Institutional Framework | 10% | Climate events can test management's capacity to handle short and long-term challenges to its economy, finances, and infrastructure. Issuers with established and well-developed emergency management, financial, capital and debt plans will be best suited to overcome climate stressors. |
| | | Operating History | 10% | |
| Debt/Pensions | 20% | Debt to Full Value | 5% | Issuers may be subject to increased debt burdens to finance the cost to repair or replace infrastructure assets. Issuers with already high debt obligations will be stressed to accommodate new burdens into their existing debt portfolios. Entities with low, manageable debt profiles will benefit from having capacity to incorporate obligations to finance capital improvements. |
| | | Debt to Revenue | 5% | |
| | | Moody's-adjusted Net Pension Liability (3-year average) to Full Value | 5% | |
| | | Moody's-adjusted Net Pension Liability (3-year average) to Revenue | 5% | |

*Source: Moody's Investors Service*

An example of this analysis was employed in the wake of Hurricane Irma in Florida. Analysts focused on available issuer liquidity to address current and projected infrastructure damage, as well as receipt of FEMA assistance in areas that had been declared a federal disaster. The size and diversity of the local economies was also a key component in our assessments of credit quality after the storm.

Recognition of the impact of climate risks also informs our qualitative discussions with management to better understand climate change preparedness and planning. As such, analysts for credits with heightened exposure to climate risks focus on current and future mitigation steps that the issuer plans to take, and the impact on of those provisions on the issuer's debt, financial and economic profiles.

## Local, state and federal tools for immediate response and long-term recovery enhance resilience to credit risks of climate shocks

US issuer resilience to extreme climate events is enhanced by a variety of local, state and federal tools to improve immediate response and long-term recovery from climate impacts. The availability of resources at multiple layers of government is an important element that broadens the response capabilities of local issuers and their ability to mitigate credit impacts. Even small localities that may have otherwise been overwhelmed by the cost or logistics of an extreme weather event can benefit from the deployment of substantially broader state and federal aid.

US local governments are typically the first line of defense against climate events, with resources aimed primarily at immediate response. This includes being the first provider of emergency services, administering local emergency operations plans and coordinating the delivery of state emergency resources as needed.

State governments monitor and evaluate the effectiveness of local response efforts and, if needed, provide both immediate response and long-term recovery assistance. If local resources are insufficient to adequately respond to the climate shock, the state can declare a state of emergency, which activates state disaster preparedness plans and attendant resources. For events that exceed the capacity of the state, federal aid is requested. The states work with the federal government to deliver emergency services and long-term recovery assistance.

Under FEMA's broad direction, the federal government coordinates the provision of essential emergency response services through a variety of federal agencies. These services include, among others, transportation, communications, public works and engineering, mass care, food, energy, and search and rescue.

The federal government also provides aid aimed at long-term economic recovery. A range of federal agencies administer more than two dozen programs to support recovery post-climate shock. These include programs to restore and preserve agricultural land, loans for businesses that have suffered physical damage, tax relief for casualty and disaster losses, crop insurance, disaster-driven unemployment assistance and support for infrastructure repair, public safety, health and sanitation. Other federal programs and organizations like the US Army Corps of Engineers assist with adaptive measures such as building and reinforcing dams, levees and water infrastructure.

## Case study: Hurricane Sandy

Hurricane Sandy made landfall in New York City (Aa2 stable) on October 29, 2012, causing billions of dollars of economic damage. The storm's impact was exacerbated by the effects of rising sea levels. Despite significant economic disruption, the city maintained its rating and outlook following the storm due to its resilient and exceptionally large and diverse economy, solid financial position underscored by strong liquidity, and financial support via federal diaster and rebuilding aid.

According to the National Oceanic and Atmospheric Association, sea levels near the location of Hurricane Sandy's occurrence have risen by more than one foot since the mid-19th century, primarily due to an increase in ocean volume stemming from rising temperatures. Higher sea levels along the eastern seaboard are forecast to increase coastal high water levels and exacerbate future storm surges.

FEMA's ability to provide federal funding for disaster relief is viewed as a credit strength of US state and local governments, and bolsters these entities' ratings. The rationale is in part due to the fact that FEMA generally pays not less than 75% of emergency response and debris cleanup costs. In practice, the agency often pays 90% or more[8]. In the case of Hurricane Sandy, FEMA paid 100% of certain emergency response and cleanup costs. The US Congress further enhanced disaster relief funding for Sandy-impacted governments by appropriating $48 billion in supplemental funding[9], which helped finance some of the NYC Special Initiative for Rebuilding and Resiliency (storm resiliency and climate change mitigation projects). The combination of Community Development Block Grants, FEMA and National Flood Insurance Program housing aid, other supplemental federal funds and the Sandy supplemental measure provided additional resources to pay for unfunded portions of the plan and mitigate the financial impact on the city's balance sheet to support its rating.

Economic resilience characterized by a strong cash position and institutionalized budgetary controls minimized the storm's credit impact, despite increased sea level rise and consequent exacerbated coastal flooding. In addition, FEMA's ability to intercede and help cover 100% of the city's emergency response and cleanup costs played a critical role in maintaining the city's credit strength following the storm. As a result of its strong reserves, budgeting practices and FEMA's financial assistance, the city's general obligation maintained its Aa2 rating and stable outlook[10].

# Appendix

Exhibit 13

**Indicators used to illustrate US states' climate change exposure**

| Factor | Description | Sources |
|---|---|---|
| GDP Coastal Counties/Total State GDP, 2016 | Total gross domestic product of Coastal Counties as a percent of state gross domestic product, 2016. Measures the extent to which a state's economic activity is concentrated near the coast and points to the economic risks of rising sea levels and coastal storms including the costs of property damage and infrastructure hardening. | US Bureau of Economic Aanalysis and Moody's Analytics. |
| Tropical Cyclone Damage, 1980-2017/State GDP, 2016 | Total damage from "billion dollar" tropical cyclones (hurricanes) from 1980 to July 2017 in CPI -adjusted dollars, as a percent of 2016 state GDP. Measures the extent to which a state is prone to damage from large coastal storms. | NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017), https://www.ncdc.noaa.gov/billions, and US Bureau of Economic Analysis. |
| Coastal Dwelling Units in 100/500 Year Floodplains/Total Coastal Dwelling Units | Total number of Coastal County dwelling units located in the 100-year or 500-year floodplain, as a percentage of total Coastal County dwelling units. Provides an indication of the extent to which, based on local topography, property in Coastal Counties is vulnerable to sea level rise and coastal storms. | NYU Furman Center, https://www.floodzonedata.us. |
| Damage from Non-Tropical Cyclone Weather Events, 1980-2017/State GDP, 2016 | Total damage from "billion dollar" weather events other than tropical cyclones (i.e. droughts, flooding, freezes, severe storms, wildfires and winter storms) from 1980 to July 2017 in CPI -adjusted dollars, as a percent of 2016 state GDP. Measures the extent to which a state is prone to severe weather events other than coastal storms. | NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017), https://www.ncdc.noaa.gov/billions/, and US Bureau of Economic Analysis. |
| Non-Coastal Dwelling Units in 100/500 Year Floodplains/Total Non-Coastal Dwelling Units | Total number of non-Coastal County dwelling units located in the 100-year or 500-year floodplain, as a percentage of total non-Coastal County dwelling units. Provides an indication of the extent to which, based on local topography, property in non-Coastal Counties is exposed to flooding due to severe storms and similar events. | NYU Furman Center, https://www.floodzonedata.us. |
| Agricultural, Forestry, Fishing and Hunting/Total State GDP 2016 | Indicates risks to agriculture and related industries of rising temperatures, increased or decreased rainfall, and droughts, noting agriculture in some states is likely to benefit from climate change. | US Bureau of Economic Aanalysis and Moody's Analytics. |

"Coastal Counties" are counties defined as Atlantic, Gulf and Pacific Coastal Shoreline Counties by NOAA and consist of counties that are directly adjacent to open ocean and major estuaries.
*Source: Moody's Investors Service*

## Moody's related research

### Sector in-Depths:

» Environmental Risks – Sovereign: How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issuers, November 7, 2016

» Cross-Sector – Global: Moody's Approach to Assessing the Credit Impacts of Environmental Risks, November 30, 2015

» Environmental Risks: Heat Map Shows Wide Variations in Credit Impact Across Sectors, November 30, 2015

» Environmental, Social and Governance (ESG) Risks – Global: Moody's Approach to Assessing ESG Risks in Ratings and Research, September 8, 2015

### Sector Comment:

» Environmental Risks: Paris Agreement to Take Effect, Adoption of Carbon Reduction Policies to Accelerate, October 2016

To access any of these reports, click on the entry above. Note that these references are current as of the date of publication of this report and that more recent reports may be available. All research may not be available to all clients.

## Endnotes

1 National Ocean Service, National Oceanic and Atmospheric Administration

2 Economic Risks of Climate Change: An American Prospectus by Houser, Hsiang, Kopp, Larsen et al

3 Center for Disease Control and Prevention, MMWR July 4, 2003

4 2014 National Climate Assessment, US Global Change Research Program

5 MOODY'S DOWNGRADES RATINGS ON CITY OF NEW ORLEANS GENERAL OBLIGATION BONDS AND PENSION OBLIGATION BONDS, November 4, 2005

6 New Orleans (City of): High Profile New Issue, May 2, 2007

7 MOODY'S ASSIGNS Aa3 RATING WITH STABLE OUTLOOK TO CITY OF HOUSTON (TX) SERIES 2006A TAXABLE PENSION OBLIGATION BONDS, SERIES 2006B PUBLIC IMPROVEMENT REFUNDING BONDS, AND SERIES 2006C CERTIFICATES OF OBLIGATION, March 6, 2006

8 New York City Storm Resiliency Plan Anticipates Federal Funds, a Credit Positive, June 17, 2013

9 The supplemental federal funding was reduced to $48 billion from $51 billion due to US federal budget sequestration.

10 Moody's assigns Aa2 rating to $850 million of City of New York general obligation refunding bonds, December 6, 2012

REPORT NUMBER 1071949

## CLIENT SERVICES

| | |
|---|---|
| Americas | 1-212-553-1653 |
| Asia Pacific | 852-3551-3077 |
| Japan | 81-3-5408-4100 |
| EMEA | 44-20-7772-5454 |

MOODY'S INVESTORS SERVICE