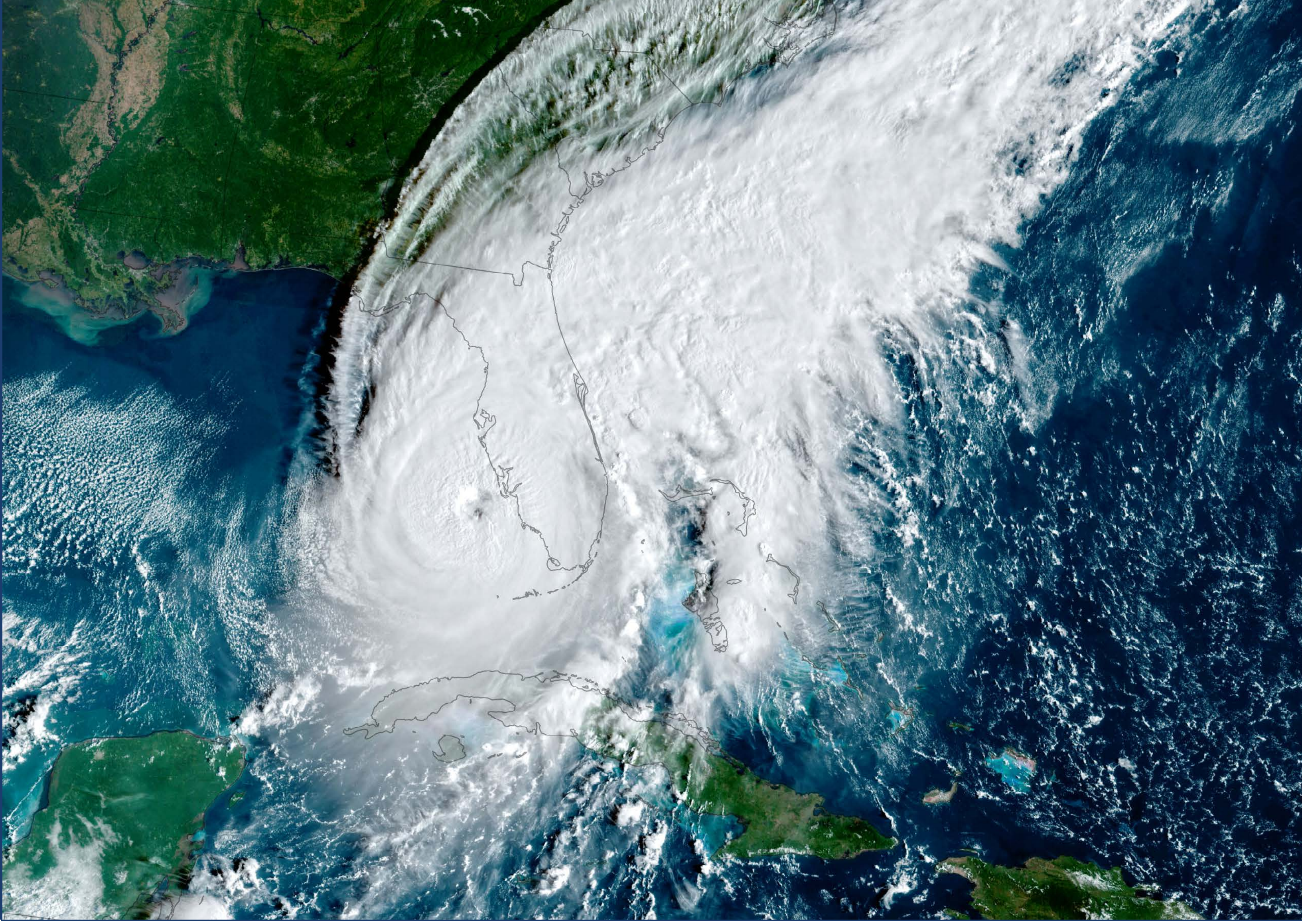


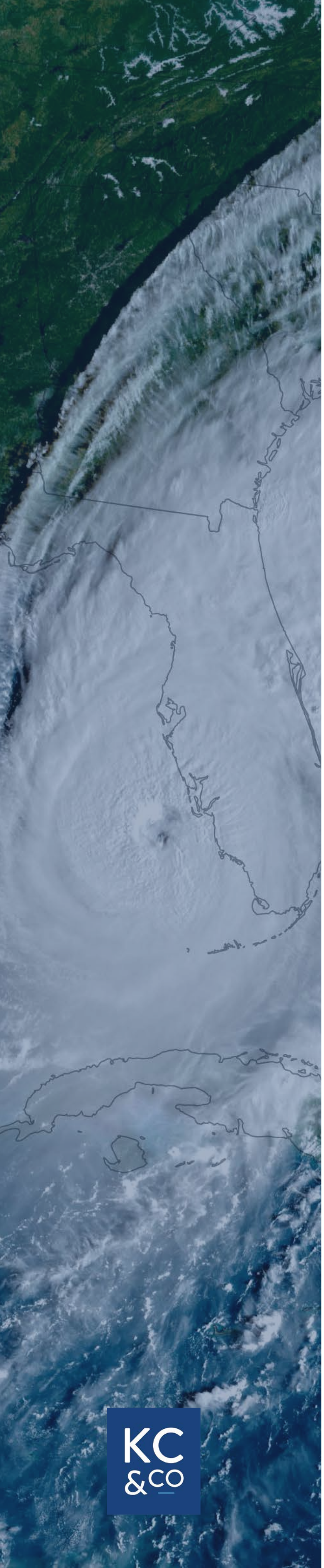
KCC WHITE PAPER

2022 North Atlantic Hurricane Season in Review

Including Post-Event Damage Surveys for Hurricane Ian

April 2023

The Innovation and Technology Leader in Catastrophe Risk Modeling



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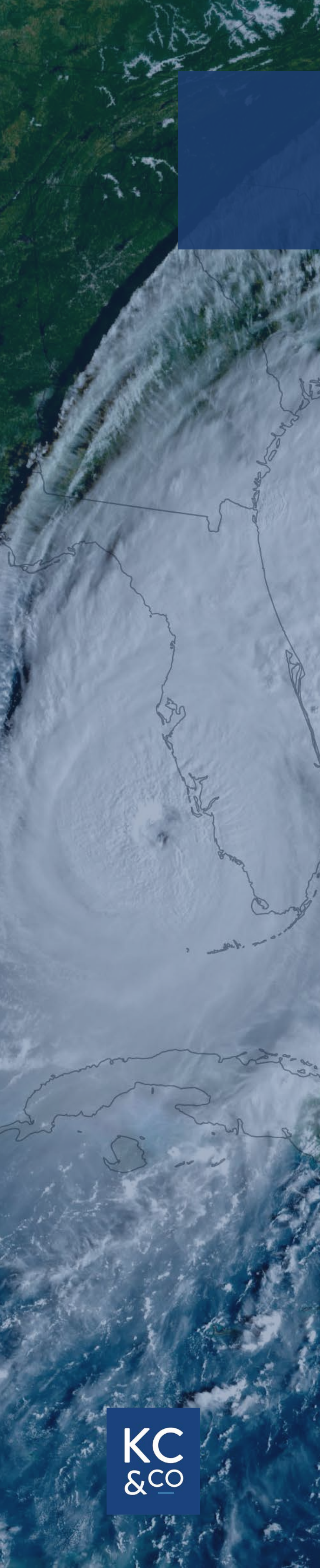
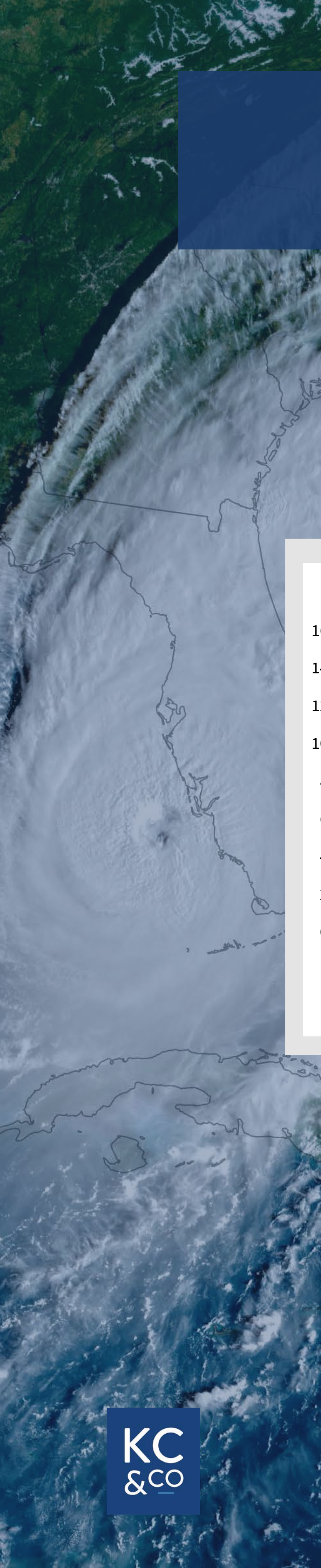
Cover Image: Satellite view of Hurricane Ian via NASA Earth Observatory



Season Highlights

- Fourteen tropical cyclones formed in the North Atlantic Basin in 2022, eight of which became hurricanes and two of which became major hurricanes (at least Category 3).
- Three named storms made landfall in the US, including two hurricanes.
- Hurricane Ian was the only major hurricane to make landfall in the US in 2022, impacting Florida with maximum sustained winds of 150 mph at landfall near Cape Coral.
- Hurricane Nicole, which made landfall on November 10th, set a record for the latest date in the year that a hurricane has made landfall along the Florida east coast, and was the second latest landfalling storm in US history.
- Although the season was only slightly above average in key respects, underlying trends influenced by climate change continued, particularly with high sea-surface temperatures (SSTs) supporting rapid intensification.
- The three-year period of 2020, 2021, and 2022 marks the first time in the historical record that hurricanes with maximum winds of 150 mph or greater have made landfall in the US in consecutive years (Laura, 2020; Ida, 2021; Ian, 2022).
- Compared with prior seasons, the 2022 North Atlantic Hurricane season saw a roughly average number of storms, but total insured losses were well above average, due to Hurricane Ian.
- Total privately insured losses from all 2022 events are expected to be $64 billion, which includes residential, commercial, industrial properties, and automobiles.

Multiple tropical cyclones in the Atlantic in September 2022 (via NASA)

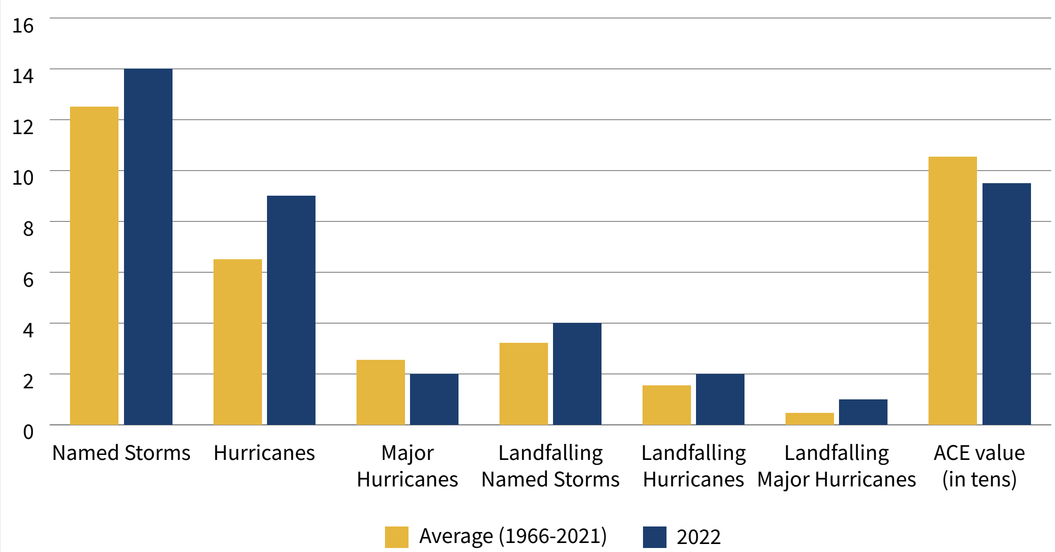


Meteorological Overview

While 2022 was forecast to be another active year with respect to North Atlantic hurricanes, on balance it was only slightly above average. Three named storms made landfall in the US, with Hurricane Ian having the largest impact of the season.

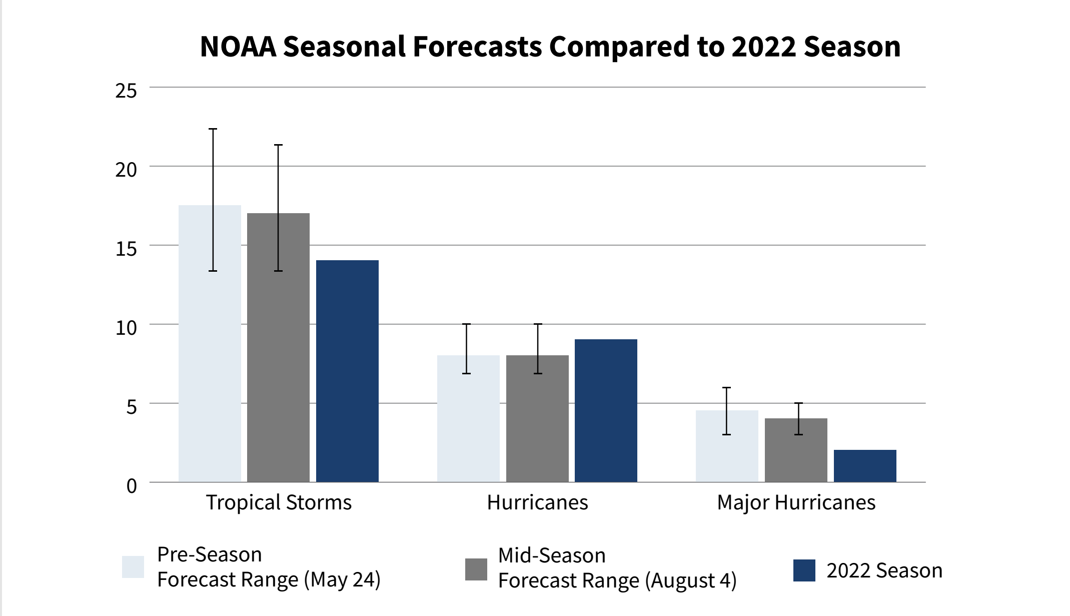
The number of major hurricanes was below average, as was the Accumulated Cyclonic Energy (ACE)—a measure of the energy produced by all tropical cyclones in a season. Meanwhile, the numbers of named storms and hurricanes were above average, but not record-setting.

2022 Season Activity Compared with Historical Activity



The National Oceanic and Atmospheric Administration (NOAA) released forecasts in both May and August that predicted an above-average season—predictions driven primarily by an ongoing La Niña. In general, La Niña conditions, when the east Pacific is cooler, correspond to more active hurricane seasons, while El Niño conditions, when the east Pacific is warmer, correspond to less active hurricane seasons. La Niña conditions can cause a reduction in the vertical wind shear over the Atlantic Ocean, improving the environment for tropical cyclone formation and intensification.

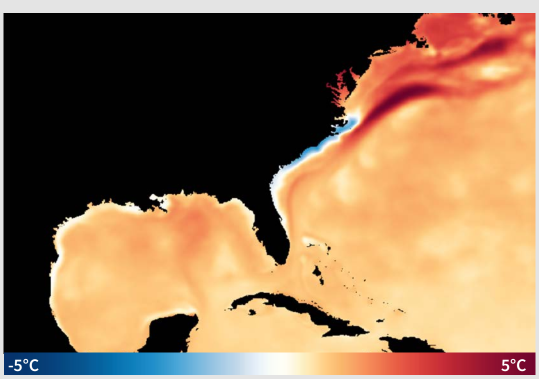
The season finished at the low end of NOAA's prediction for the number of tropical storms, in the middle of the forecast range for hurricanes, and below their prediction for major hurricanes.



This lower than predicted activity was due in part to higher than anticipated vertical wind shear in the Main Development Region of the tropical Atlantic, especially during the first half of the season. Notably, there was no tropical storm activity for nearly two months between Colin's dissipation on July 2nd and Danielle's formation on September 1st. Dry air, African dust, and unfavorable winds suppressed tropical development in July and August, contributing to the unusual mid-season lull. After an active September that saw the formation of four hurricanes, including the season's two major hurricanes, October brought a return of high vertical wind shear to the Caribbean Sea and tropical Atlantic Ocean.

Climate change is driving an increase in Sea Surface Temperatures (SSTs) in the Atlantic Basin and, as a result, rapid intensification—which is closely linked to both SSTs and climate change—has been observed with more frequency in this region. A hurricane needs three main ingredients to rapidly intensify: low vertical wind shear, high ocean heat content, and high SSTs. SSTs in the Atlantic were above average in 2022.

Rapid intensification is an increase in maximum wind speeds of 35 mph or more within a 24-hour period.



2022 sea surface temperature anomaly (via NOAA)

Hurricane Ian underwent rapid intensification twice—first leading up to its Cuba landfall, and again before its Florida landfall, when its peak winds increased by 35 mph from 120 mph to 155 mph in less than 10 hours.

As ocean temperatures continue to increase due to climate change, rapid intensification of storms is likely to become even more frequent. In addition to potentially stronger storms forming in the Atlantic, last-minute intensification before landfall adds uncertainty to the storm forecast, makes projecting potential coastal impacts more challenging, and complicates disaster preparedness.

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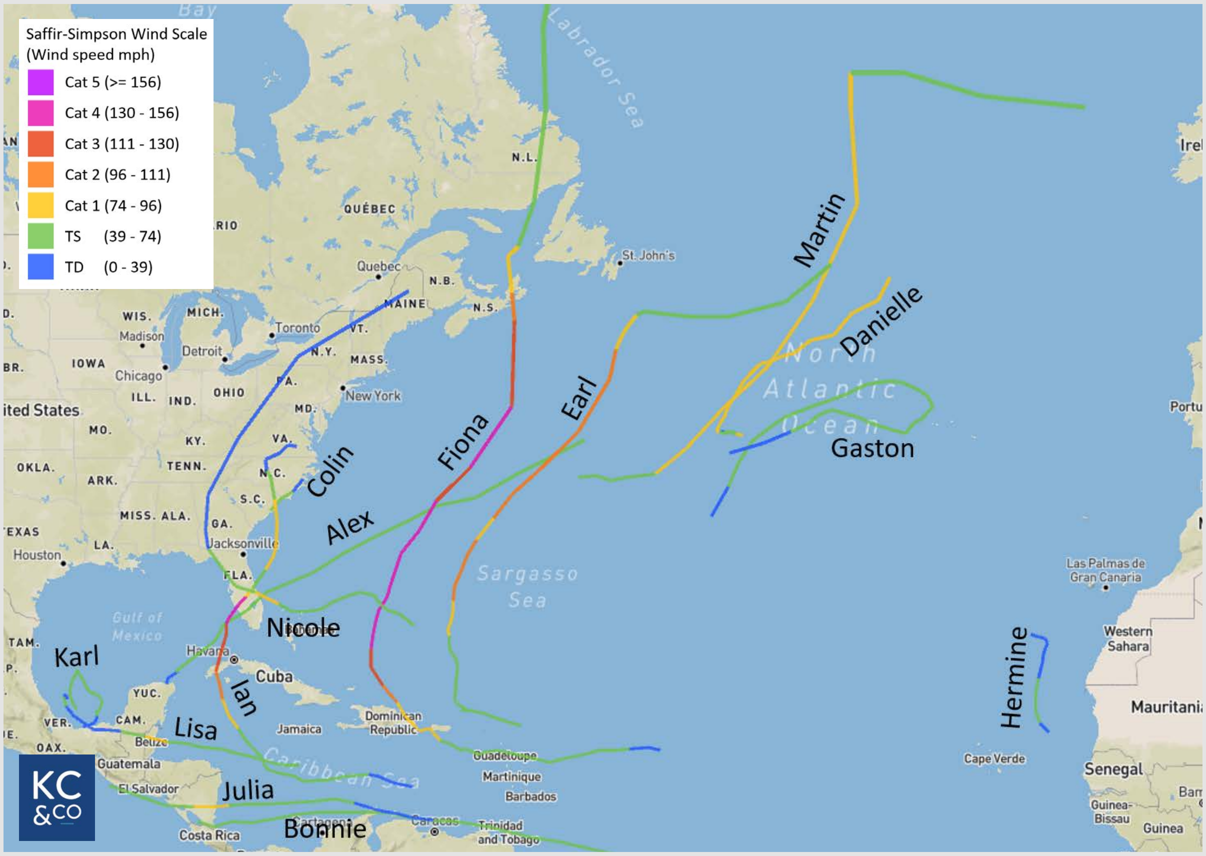
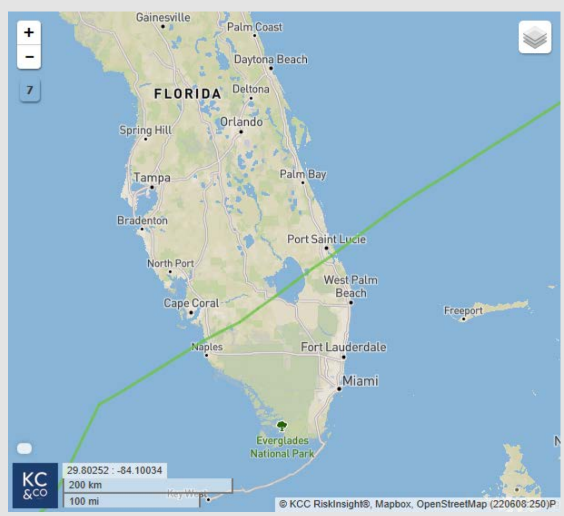


Named storms of the 2022 North Atlantic hurricane season

Tropical Storm Alex

Tropical Storm Alex originated from the remnants of Eastern Pacific Hurricane Agatha. A tropical depression reached the southwestern coast of Florida on June 4th and continued across the peninsula before moving off the east coast. After moving northwest of the Bahamas, the disturbance organized into Tropical Storm Alex. Once Alex passed north of Bermuda, the storm transitioned to post-tropical and dissipated a couple of days later near Norway.

Alex produced heavy rainfall and flooding across South Florida with numerous locations reporting between 10 and 15 inches of rain. The primary impacts from Alex were urban flooding and power outages. Insured losses were minimal.



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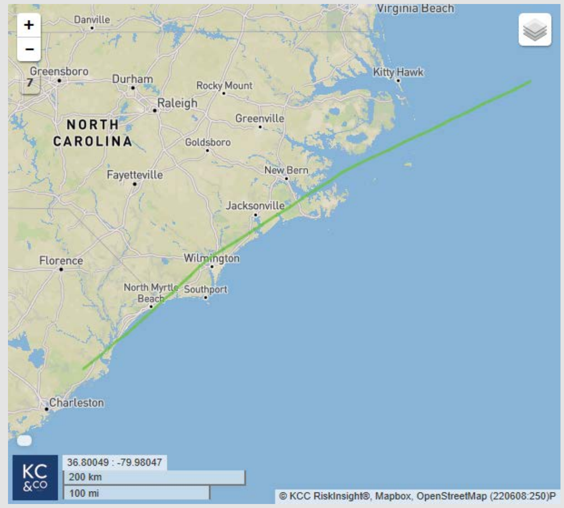
Tropical Storm Colin

Tropical Storm Colin formed unexpectedly on the morning of July 1st. A small area of low pressure formed in a trough offshore of Savannah, Georgia, then moved inland across South Carolina where deep, rapidly organizing convection formed. This convection drifted offshore and became more organized off the coast of South Carolina. Colin became a tropical storm with 40 mph winds just to the northeast of Charleston before turning northeast and dissipating a day later.

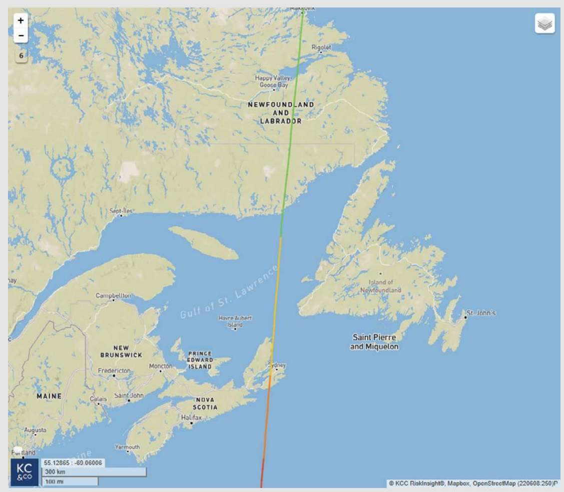
The primary impacts from Colin included localized heavy rainfall over coastal areas and minor flooding. KCC estimates total insured losses of about $10 million for Tropical Storm Colin.

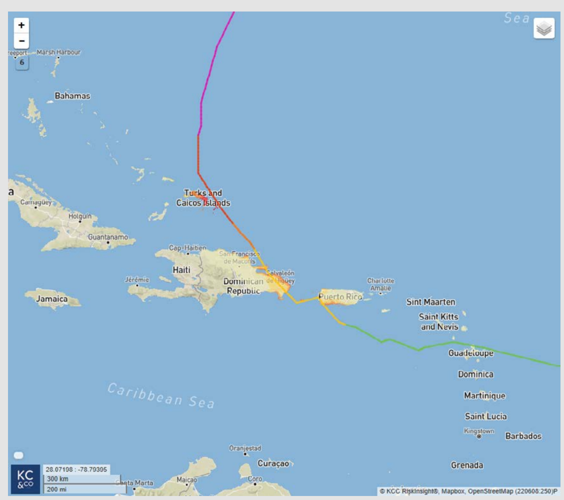


Hurricane Fiona

Hurricane Fiona formed from a tropical wave that emerged off West Africa before developing into a tropical depression east of the Leeward Islands on September 14th and became a tropical storm the next day. Fiona made landfall along the southwestern coast of Puerto Rico on September 16th and again in the Dominican Republic shortly thereafter. Fiona strengthened into the first major hurricane of the season following the second landfall, and then fluctuated between Category 3 and 4 intensities as the hurricane passed Bermuda. Fiona transitioned into a powerful extratropical cyclone that struck Nova Scotia with 105 mph winds on September 24th and set a record for the deepest low-pressure system to hit Canada. The remnants of Fiona finally dissipated near Greenland on September 28th.

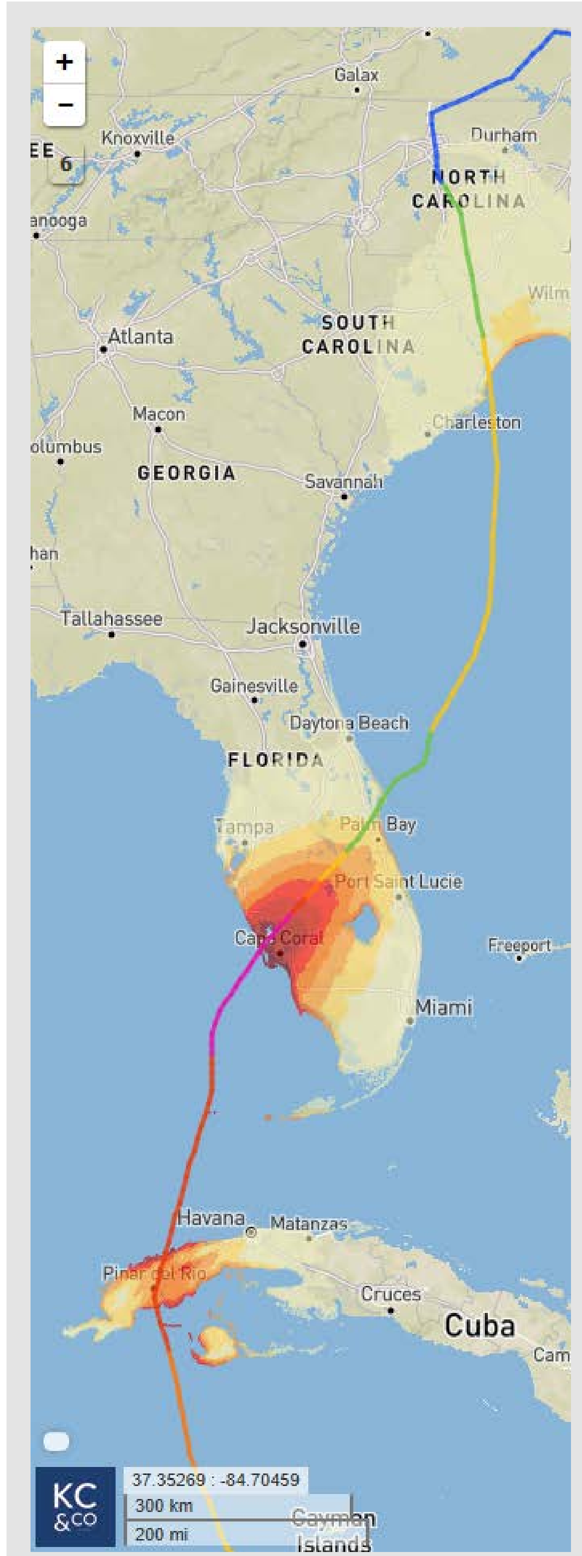
Strong winds and heavy rainfall from Hurricane Fiona caused widespread damage throughout the Caribbean. Puerto Rico suffered the worst impacts, with roads washed away, roofs torn from houses, and bridges destroyed. Large portions of the Dominican Republic, Turks and Caicos, and Bermuda lost power as well, and sustained moderate damage. KCC estimates about $306 million in insured losses from this event across 18 Caribbean nations. In Eastern Canada, Fiona caused flooding, loss of power, and damage to homes.





Hurricane Ian

Ian began as a tropical depression that formed in the Central Caribbean Sea on September 23rd. The storm underwent rapid intensification before making landfall on September 27th near La Coloma, Cuba as a Category 3 hurricane with maximum sustained winds of 125 mph.



After crossing Cuba, Ian again intensified rapidly just off the coast of southwest Florida with peak winds increasing from 120 mph to 155 mph in less than 10 hours. This intensification proceeded from an eyewall replacement cycle that completed the night before landfall and caused the windfield to expand.

Ian reached a peak intensity of 160 mph (Category 5) before weakening slightly and making landfall in Florida on September 28th near Cayo Costa as a strong Category 4 storm with 150 mph winds. After landfall, Ian slowly moved northeast across the peninsula, bringing widespread destruction. Most of the Florida peninsula experienced at least tropical storm force winds.

After moving offshore along the east coast of Florida as a tropical storm, Ian reorganized into a Category 1 hurricane and made a second US landfall near Caines, South Carolina on September 30th with 85 mph winds.

In nominal dollars (dollars not adjusted for population growth or inflation), Hurricane Ian will be the largest hurricane loss in Florida's history. The total economic damage is estimated to be well over $100 billion, including uninsured properties, damage to infrastructure, and other cleanup and recovery costs. Based on the high-resolution KCC Hurricane Reference Models, KCC estimates that the privately insured loss from Hurricane Ian will be close to $63 billion, with $200 million in the Caribbean and the rest from wind, storm surge, and inland flood losses in the US.

The Florida component of the loss from Hurricane Ian includes an assumption that there will be a high number of litigated claims, comparable to the excess litigation experienced in Hurricanes Irma and Michael. Additionally, the proportion of auto losses in Ian is estimated to be higher than average due to widespread storm surge.

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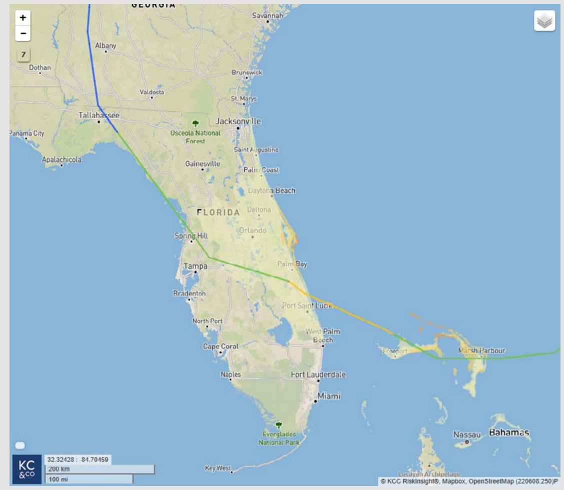
Hurricane Nicole

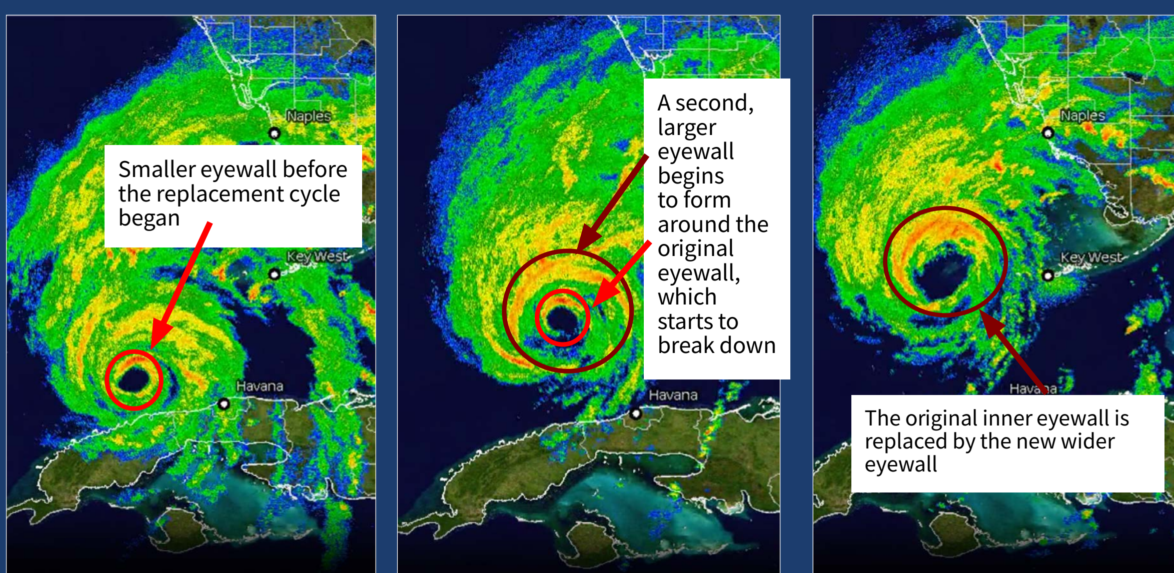
Late in the season, Nicole formed as a subtropical cyclone and transitioned to a tropical storm on November 8th before making landfall on Great Abaco Island in the northwestern Bahamas the next day. Nicole became a hurricane just before making landfall on Grand Bahama Island on the evening of November 9th. Early the next morning, Hurricane Nicole made landfall along the east coast of Florida near Vero Beach as a Category 1 storm and continued northwest through Florida before dissipating over the Carolinas.

The large size of Hurricane Nicole led to storm surge and coastal flooding across a large portion of the Florida east coast, with insured losses projected to be $870 million from wind and surge.



Eyewall replacement cycle is a process in mature hurricanes in which the inner eyewall (a band of strong convection and winds surrounding the eye of the hurricane) is replaced by a new, stronger outer eyewall. Hurricanes typically stall or decrease in intensity during the cycle, but often reintensify after the cycle is complete.

The radar images below show Hurricane Ian's second eyewall replacement cycle that occurred from September 27-28.



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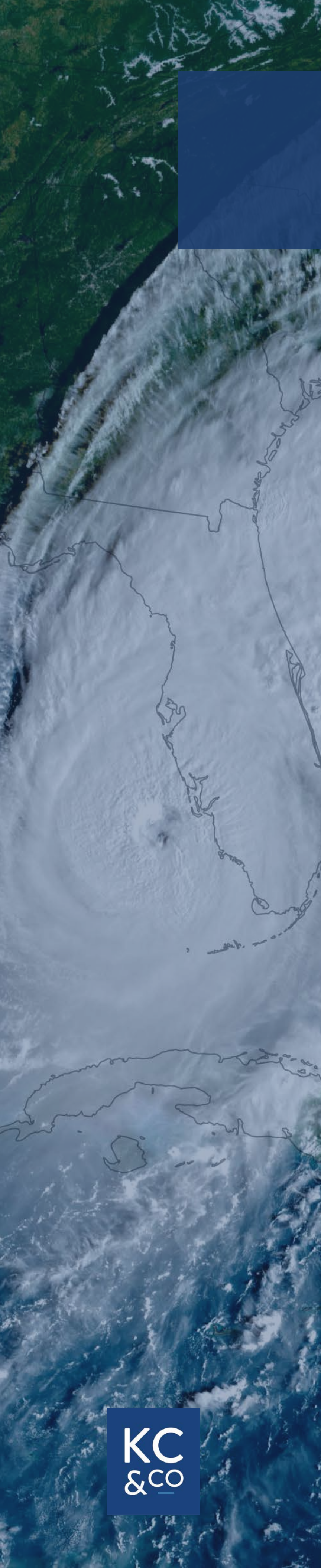


Industry Losses

Throughout the 2022 hurricane season, the KCC US Hurricane Model was used to produce real-time loss estimates for individual insurer portfolios and for the industry as a whole. When a storm threatens the Caribbean or US coast, KCC uses projected tracks from the National Hurricane Center (NHC) to produce high-resolution wind and coastal flood footprints for client download. KCC client companies can then perform detailed claims and loss analyses as individual events develop to proactively manage their claims adjusting activities.

In 2022, five named tropical cyclones impacted the United States and Caribbean, including three hurricanes. Insured losses were above average and much higher than losses in 2021 and 2020, despite the lower activity.

The 2022 hurricane season insured losses were driven almost entirely by Hurricane Ian, with two smaller events in the US and one event in the Caribbean. Total insured losses from the 2022 hurricane season are estimated to be $64 billion. KCC's estimated industry losses include wind and privately insured flood losses to residential, commercial, industrial properties, and automobiles. They do not include National Flood Insurance Program (NFIP) losses.

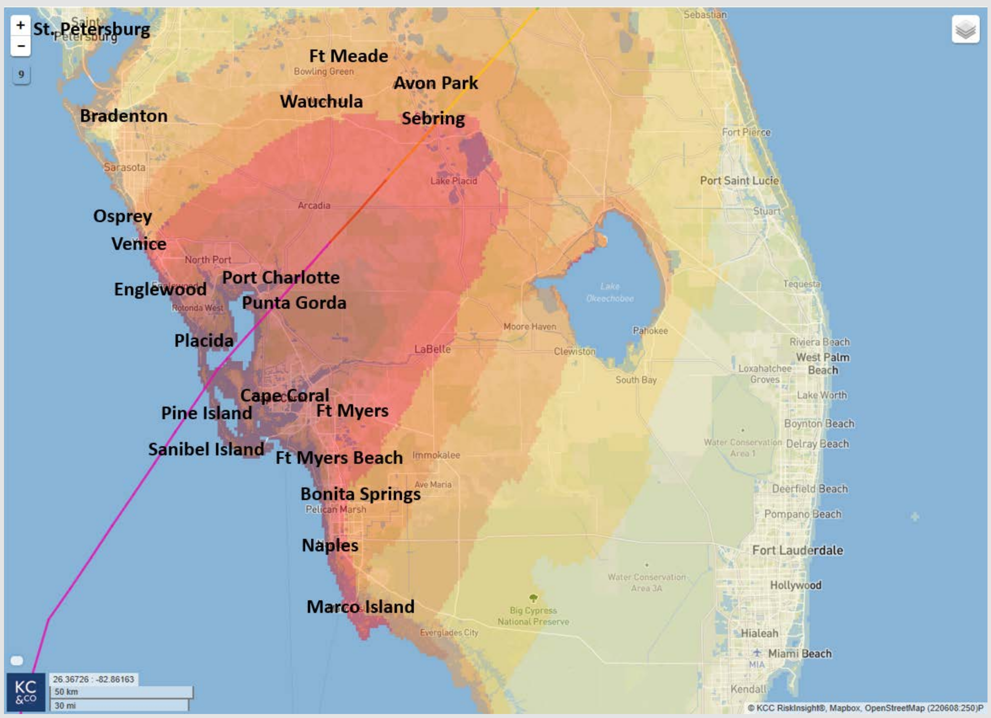
Storm Name	Dates Active	Category at Peak Intensity	Max Wind (mph)	Areas Affected	Insured Loss ($million)
Alex	June 5-6	TS	70	Yucatán Peninsula, Western Cuba, Florida, Northern Bahamas, Bermuda	No estimated losses
Colin	July 1-2	TS	40	Northeastern Florida, Georgia, South Carolina, and southeastern North Carolina	10
Fiona	Sept 14-24	4	130	Lesser Antilles, Puerto Rico, Dominican Republic, Eastern Bahamas, Turks and Caicos Islands, Bermuda, Eastern Canada	306*
Ian	Sept 23-30	5	160	Trinidad and Tobago, Venezuela, Colombia, ABC islands, Jamaica, Cayman Islands, Cuba, Florida, Georgia, South Carolina	63,000
Nicole	Nov 7-11	1	75	The Bahamas, Florida	870

**Note: the KCC loss estimate for Fiona does not include Canada.*

Hurricane Ian Post-Event Surveys

In the days following Hurricane Ian in October 2022, KCC scientists and engineers conducted a post-event survey in Florida, followed by a second damage survey in March 2023. During the first survey, the team surveyed locations throughout the impacted area. The most recent survey focused on the heavily impacted coastal areas and the extent of rebuilding and recovery six months after the event.

KCC's damage survey team selected locations that included a variety of wind speed regimes as well as both coastal and inland locations.



Locations surveyed by KCC post-event survey team

Category 4 Winds

Fort Myers Beach, Sanibel Island, and Pine Island experienced Category 4 wind speeds.

The most frequently observed impacts in this wind speed regime were severe wind-driven damage to roofs and walls. Category 4 wind speeds can cause structural damage to roof decks and roof frames, which leads to progressive interior damage from water and wind infiltration. In addition, once the roof is compromised, the walls can collapse, leading to total loss.

Many roofs were severely damaged by high winds and wind-borne debris. Roof damage increases internal pressure on the wall systems and ultimately leads to structural damage.

Wind damaged the roof structures of single-family homes in Fort Myers Beach, which led to progressive damage to the wall structures and total losses in many cases.

Extreme structural damage to the wood frame wall of this Pine Island home led to severe interior damage. Damaged windows and breaches on the gable caused higher pressure on the roof and wall. The wall structure in this building collapsed even before the roof structure failed.

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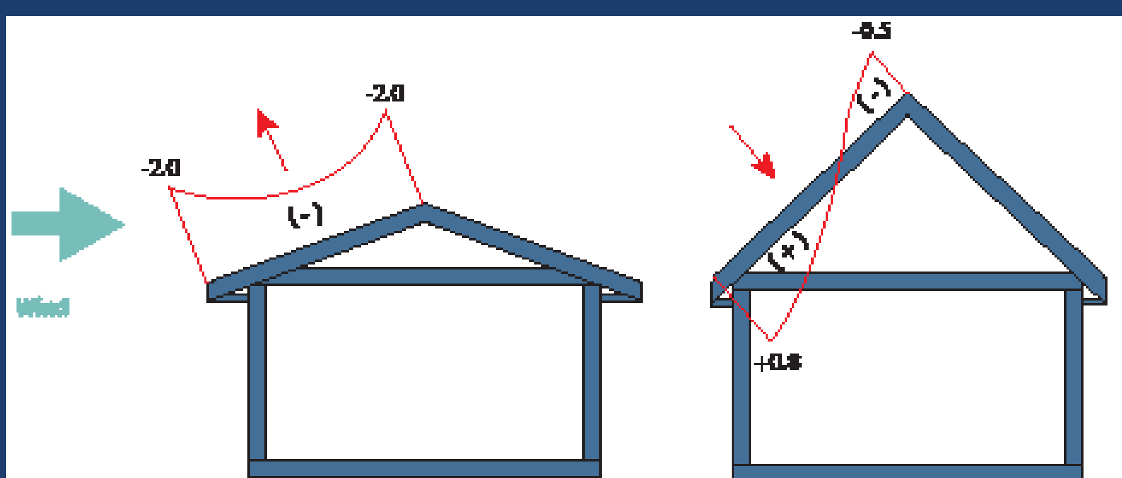
Low-sloped and flat roofs, which are common in multifamily buildings, also failed in the highest wind speeds, leading to progressive damage and total losses.

The flat wooden roofs on these multifamily residences were compromised, which increased the pressure on openings and walls and caused them to fail. Once the building envelope is compromised, wind and water can fully damage the interior, resulting in a total loss.

Low-sloped and flat roofs are more vulnerable to wind than steeper sloped roofs with the same covering. As the wind direction and the angle of the roof become closer to parallel, the pressure above the roof decreases compared to the pressure below the roof, which creates negative pressure (also known as suction pressure or uplift) on the roof structure.

The negative pressure of a low-sloped roof is greatest at the roof edges and ridges (ridge pressure coefficient of -2.0 in the diagram). Steep-sloped roofs are aerodynamically favorable because the magnitude of negative pressures created at the roof edges and ridges decreases (ridge pressure coefficient of -0.5 in the diagram) as the angle increases, creating lower forces. When the roof slope is steep enough, the wind pressure on the windward size of the roof becomes positive rather than negative.



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Older single-family homes experienced more extensive damage than more recent construction, as expected.

The detachment of roof components is the most common reason for a loss of structural integrity due to high winds. These Pine Island homes were built before the first wind engineering based design requirements, so the wind speeds from Hurricane Ian exceeded the design wind speeds.

Neighboring buildings can illustrate how age and construction type have a major impact on damage.

The home on the left was constructed of wood frame with a shingle roof in 1972, while the home on the right was constructed of masonry with a metal roof in 1997. The wood frame home was completely destroyed, while the masonry home sustained only minor screen damage and water leakage.

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Commercial buildings also performed differently based on age and construction type. Older, low-rise commercial buildings, particularly those constructed of wood frame or masonry, sustained severe damage, while concrete and steel buildings fared better. The stronger connections in the roof and wall systems of concrete and steel structures make them more resistant to high winds.

Masonry commercial buildings in Fort Myers Beach (left) sustained extensive roof covering and decking damage, which caused progressive interior damage. Reinforced concrete buildings (right) were minimally damaged in most cases.

As observed in previous events, metal roofs generally perform better than other roof covering types, but they can fail in Category 4 winds. Defective engineering, malfunctioning components (such as rusted panels or fasteners), or faulty installation (such as insufficient fasteners or incorrect clip spacing) are often the main reasons for metal roof failure. The KCC team observed isolated cases of metal roof damage, particularly in commercial and multifamily residential buildings.

Wind peeled the metal roof of a public building from its rafters (left) and sheared the metal roof completely off a multifamily building (right).

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Category 3 Winds

Cape Coral, Placida, Englewood, Bonita Springs, Punta Gorda, and Port Charlotte experienced Category 3 wind speeds. Category 3 wind speeds can damage roof soffits, roof coverings, and wall siding. Additionally, old or poorly constructed roof systems and unprotected openings can be damaged, leading to progressive and structural damage as in Category 4 winds.

There were several manufactured home parks in these areas and as expected, manufactured homes suffered extensive damage.

Many manufactured homes in Placida were completely destroyed with detached roofs and collapsed walls.

Nearly 90% of homes in an Englewood manufactured home neighborhood sustained some degree of damage.

Manufactured homes in Englewood sustained extensive interior damage due to water infiltration from exposed roofs and walls when the roof cover and wall siding were damaged by high winds.

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Site-built homes in Category 3 wind speeds primarily experienced roof and siding damage.

Shingle and tile roofs suffered the most extensive damage compared to metal roofs, which tend to perform better for a several reasons. First, metal roofs are made with overlapping panels that interlock on all sides. These interlocking panels increase the roof's wind resistance by preventing high winds from getting under the roof covering and creating uplift. Second, metal panels are tougher than other materials and therefore are less impacted by wind-blown debris—the roof may dent but tends not to leak or fail. Third, metal roofs are secured in place more robustly than tiles or shingles. Over time, the adhesives that hold tiles or shingles to a roof may break down, while metal roofs generally remain firmly locked in place.

Shingle (upper left) and tile (upper right) roofs were often damaged by Category 3 wind speeds, whereas metal roofs (bottom) performed better.

Many instances of siding damage were observed. Stucco siding generally outperformed vinyl siding, which was frequently damaged by suction and debris impact.

There were many instances of damaged vinyl siding (left), while heavier siding options, like stucco (right), exhibited better performance in Category 3 winds.

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The cost to repair damaged siding depends on whether it can be patched or requires complete replacement. If there is no underlying water damage from the loss of siding, it may not be necessary to replace all of it. Additionally, if the original siding is available or if there would be only a slight difference in the look of the siding, it's possible to patch it.

In many cases, minor and moderate damage to siding had already been repaired by the time of the second KCC survey.

A home in Fort Myers patched siding and soffit between the first KCC damage survey in October 2022 (left) and the second in March 2023 (right).

However, even on homes that lost only a few pieces of siding, the entire siding may need replacement if there is water infiltration, which is often not observable from the outside. Complete siding replacement may also be necessitated for cosmetic reasons when the original siding is not available.

A home in St. James City on Pine Island pictured in March 2023 (right) undergoes siding replacement after losing only part of its siding in October 2022 (left).

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Garage doors are another common mode of failure in Category 3 wind speeds, as high winds can cause garage doors to bulge and warp. At these wind speeds, garage doors are also susceptible to misalignment and jamming that may not be immediately visible. Garage doors are typically the largest opening in a home and therefore the most vulnerable to wind pressures. If a garage door is compromised, the internal pressure on the roof and walls increases and creates higher wind loads on the overall structure, which then increases the likelihood that the roof or walls will fail.

Garage doors in Cape Coral (left) and Port Charlotte (right) warped and buckled.

Similar to single-family homes, the most common forms of damage to multifamily homes included roof and siding damage.

The KCC survey team observed many instances of tile roof damage on multifamily residential structures.

The tile roof on a multifamily residential structure in Cape Coral sustained severe damage.

The roofs of multifamily buildings that sustained less damage were typically made of reinforced concrete or built-up roof systems of wood or metal decks. These built-up roof systems perform better because the multiple layers add redundancy.

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A multifamily residential structure in Cape Coral appears undamaged. The roof of this building is a built-up wood deck system, which is much more wind-resistant than tile.

Exterior Insulation Finishing Systems (EIFS) are a popular siding material for commercial and multifamily residential buildings because it is regarded as affordable, attractive, and easy to install. This type of wall siding is especially vulnerable because it is light-weight and detaches easily from the underlying structure. Wind can exploit small cracks and cause significant siding damage, which can then lead to extensive interior damage due to water infiltration.

EIFS panels peeled from a building in Cape Coral, demonstrating why it should not be used in hurricane-prone areas.

Category 3 winds typically damage the roofs, signs, siding, and signboards of commercial properties, primarily to lightweight structures such as small-scale retail stores and gas stations.

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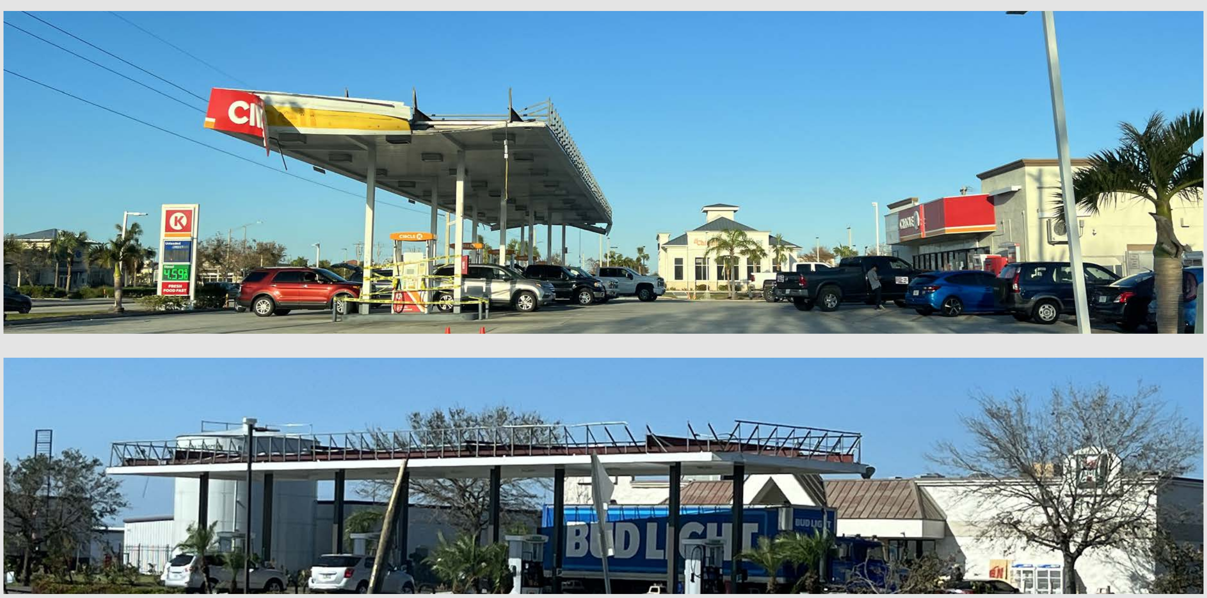
Wind-damaged signboard on a retail store in Cape Coral

This auto body shop in Port Charlotte experienced severe damage to the siding and roof. The old metal panel siding was poorly connected to the wall and roof.

Category 3 winds frequently damage the roof covering and siding of gas stations. Gas station pavilions are particularly vulnerable to wind uplift forces due to their light weight and broad surface area.



Gas station pavilions sustained heavy damage from wind uplift due to their light weight and large surface area.

Category 2 Winds

Category 2 wind speeds impacted Naples, Sebring, and Marco Island.

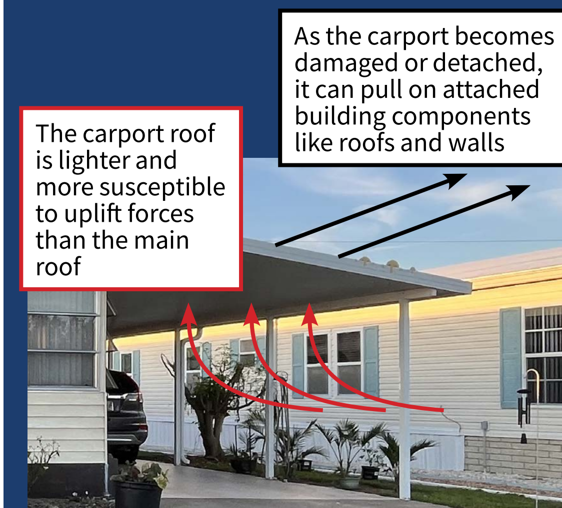
Manufactured homes in these areas experienced minor to moderate damage. Manufactured homes are susceptible to progressive damage, which can happen in two ways.

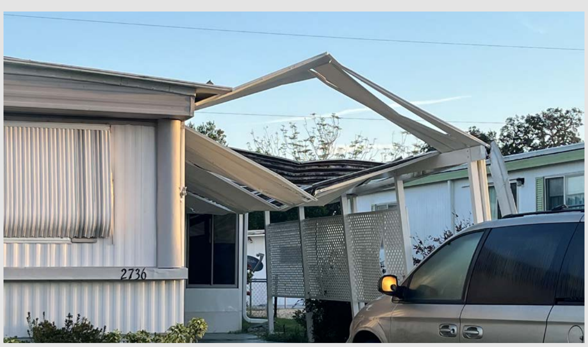
The first mode of progressive damage for manufactured homes occurs at the individual home level when roofs are damaged, which leads to progressive interior damage due to wind and water infiltration. Roofs in manufactured homes are more vulnerable than site-built homes due to weaker wind-resistance, widely used low-sloped roof shapes, and attached structures.

The second mode of damage occurs at the community level when damaged attached structures and structural components from the main buildings become wind-borne debris, which increases the chances of damage to neighboring homes.

Carports are a common feature of manufactured homes. They are typically attached where the roof meets the wall and extend above a driveway to provide overhead coverage to vehicles.

Carport damage often leads to progressive damage. When a carport detaches from the main building, it may take the roof cover, wall siding, and possibly part of the roof with it. Once the structural integrity is compromised, progressive damage and collapse of the roof and walls are possible.





In Category 2 wind speeds, attached structures, such as carports are vulnerable and can get torn off, causing progressive damage to the main buildings.

Large amounts of debris from damaged attached structures and other building components from manufactured homes increase the risk of damage to neighboring homes.

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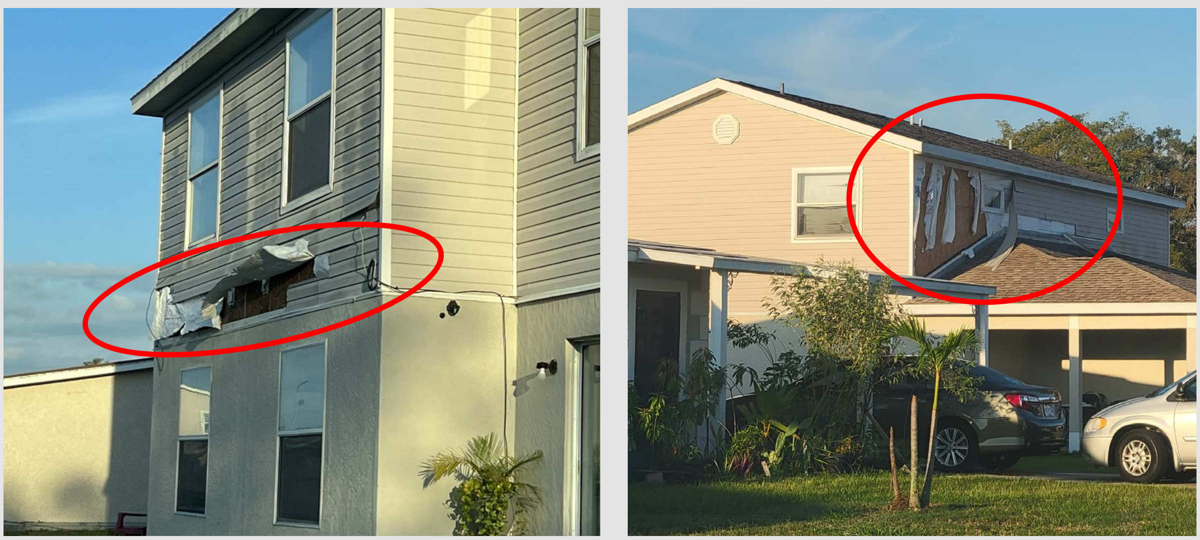
In this wind speed regime, there were also occasional instances of minor to moderate damage to the roofs and wall siding of site-built single-family homes.

Minor roof damage in Naples (left) and Marco Island (right)



Moderate wall siding damage in Sebring

Category 1 Winds

Avon Park, Venice, Osprey, and Bradenton experienced Category 1 wind speeds, which typically cause sporadic minor damage to roof soffits, roof covering, and wall siding.

Older manufactured homes can sustain significant damage, even in Category 1 winds. Poorly-connected attached structures like carports and canopies were the primary cause of significant damage in this wind speed regime.

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The attached structures of these manufactured homes were lifted up from pressure below the structure. Because these structures are connected to the roof, parts of the roof are also progressively damaged, first because of wind-induced vibration and then because of full lift off of the attached structure.

Progressive damage can lead to manufactured homes losing portions of their roofs, as shown below.

This manufactured home lost part of its roof after an attached structure was damaged.

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Soffits in site-built homes were damaged consistently in this wind speed regime. Soffit damage is typically only visible from ground-level and will not appear in aerial damage surveys.

Examples of soffit damage in Venice (left) and Bradenton (right)

A common pattern of soffit failure occurs when the wind removes the fascia and exposes the soffit edge, which allows the wind to pry it loose and strip the panels off the building.

Soffit damage also occurs when wind directed upward by the sidewall pushes up soffit panels, forcing them to come out of their channel support. Corners are especially vulnerable to this type of damage and two-story buildings are more susceptible than one-story buildings.

Soffit damage can also occur from downward pressure (also known as suction pressure) when the pressure difference between the outside and inside of the panel is so great that the soffit is pulled downward out of the channel. In most cases of soffit damage, only the soffit itself needs replacing, but water infiltration can result from even minor damage.

A soffit is the exposed siding beneath a roof's overhang. When a soffit is damaged, it can expose the interior of the building to wind-driven rain and lead to significant water damage. Under damaged soffits, the attic, interior walls, and siding are all vulnerable to water damage.

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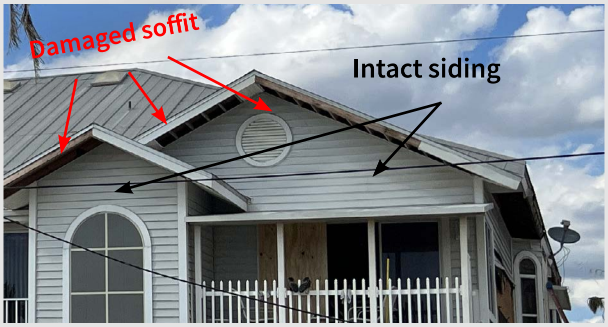
Soffit damage can necessitate complete replacement of a building's siding because wind-driven rain gets under the siding and into the walls. Rainwater can also be driven over the exterior wall into wall breaches and attic spaces. Water infiltration can then lead to significant interior damage, increasing the ultimate loss.

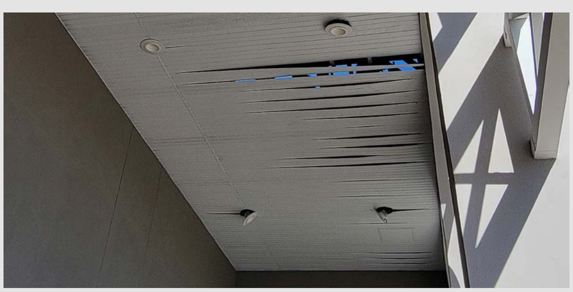
On some occasions where the soffit needs replacement, there is also a need for demolding due to water infiltration.

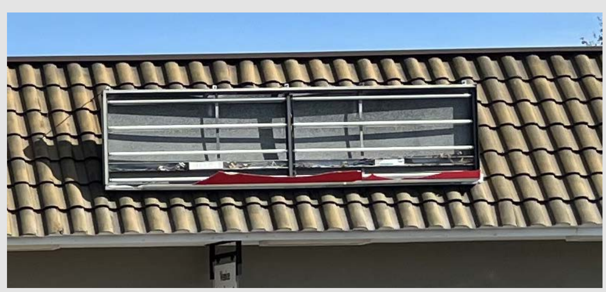


Example of siding repair following soffit damage. The siding of this home was not damaged in October 2022 (left) but was undergoing replacement in March 2023 (right), likely due to water infiltration after the soffits were damaged.

Despite the moderate wind speeds, some commercial properties sustained minor-to-moderate damage, particularly to roof coverings and tiles, exterior ceilings, and signboards.

Some older commercial properties sustained significant tile roof damage. The roof type on these buildings is similar to a flat roof, which causes high suction pressures on the tiles in the corners. Ridges are often the weaker parts of roofs because of higher suction pressures compared to other roof areas.





Damage to exterior ceiling panels caused by local wind gust effects in a long corridor (left) and damaged sign (right).

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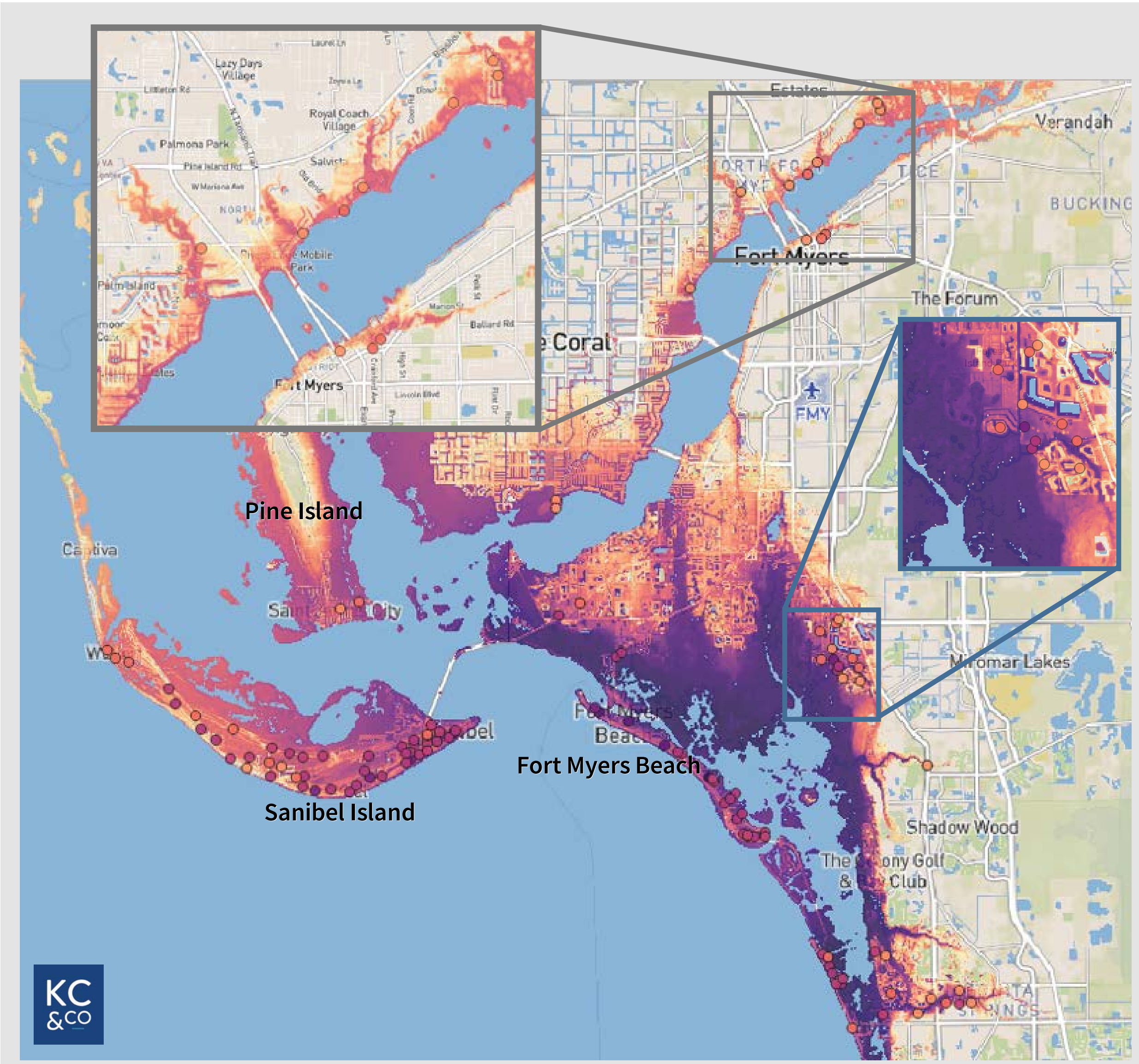
Storm Surge Damage

While storm surge damage was primarily limited to coastal areas, a few locations along rivers experienced storm surge as far as three miles inland. Storm surge heights exceeded ten feet in several locations, with a peak surge of twelve feet in Fort Myers Beach. The KCC team conducted a comprehensive damage survey throughout the impacted area.



KCC Live Event storm surge footprint for Hurricane Ian with USGS measured inundation heights

Of the areas visited during the KCC damage surveys, Fort Myers Beach experienced the highest storm surge. According to the KCC US Hurricane model, and validated by actual observations, the peak storm surge in Fort Myers Beach was over 12 feet. About 20 percent of buildings in Fort Myers Beach were total losses and more than half of those buildings were not elevated. Sanibel Island also experienced some of the highest storm surge from Hurricane Ian, with surge heights near 10 feet.

Pine Island experienced slightly lower storm surge heights than Fort Myers Beach and Sanibel Island with a maximum surge height of about eight feet. Surge heights here were lower because Pine Island was north of the peak surge and is located on an enclosed bay (meaning it is surrounded on almost all sides by other islands and does not have a coast on the open ocean).

Despite being further inland than Fort Myers Beach, Fort Myers was also impacted by storm surge because of its location along the Caloosahatchee River. The highest storm surge in Fort Myers was about five feet.

The two damage modes caused by storm surge that lead to severe or complete loss include:

1) the failure of the foundation connection (how the building is tied to the foundation), or

2) the failure of the foundation itself.

A stronger foundation connection can help protect buildings from storm surge damage. Anchor bolts create a much stronger connection than clips or nails because anchor bolts are often cast in place and connect to a concrete surface, which creates a higher load capacity. The foundation connection can fail due to either lateral loading (shear) or vertical loading (buoyancy). The foundation itself can fail due to lateral loading.

High water marks may not be observable in all buildings affected by storm surge, so other methods can be used to estimate surge height. For example, boats toppled off high supports can indicate storm surge height.

When there is a hurricane warning, boat owners tend to do one of three things:

1) securely moor the boat,

2) haul it fully out of water onto land, or

3) securely support them on tall boat stands.

If the boats were shifted or toppled off these tall stands by surge, it can be inferred that the surge height was at least the height of the stands. The boats pictured below had been secured to stands that were about ten feet high, so the surge can be estimated to be at least ten feet in this area.

This home in Fort Myers Beach (shown before Ian on the left and after on the right) was shifted off its foundation due to storm surge and sustained extensive structural damage leading to a total loss. Not only did the foundation connection fail, but the foundation itself partially collapsed because it was a relatively old building (built in 1952).

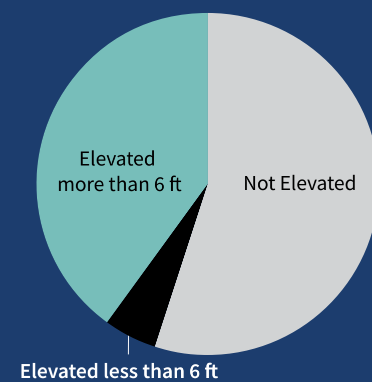
Storm surge can cause a failure of the foundation connection and foundation of coastal buildings, resulting in total losses. These homes were built on solid wall foundations, which failed due to storm surge.

Elevating the first floor of a building is a common building practice in hurricane-prone areas that can help protect against damage from storm surge. An estimated 45 percent of the buildings throughout the surveyed areas were elevated to some degree.

The proportion of elevated homes varied by location—the majority of buildings on Fort Myers Beach, Sanibel Island, and Pine Island were elevated, while less than a quarter were elevated in Fort Myers, Cape Coral, and Bonita Springs.

The homes below in Bonita Springs highlight the benefits of elevating the living space of a home. The single-story home built at ground level was fully inundated by storm surge, while the elevated home was minimally damaged.

Building Elevation Observed in Surveyed Areas



These Bonita Springs homes were impacted by similar levels of surge but while the home with a first floor at ground elevation (left) was a total loss, the main living space of the elevated home (right) was only minimally damaged.

Understandably, elevating a building is not enough to prevent damage when the storm surge is higher than the first-floor height. Additionally, because coastal areas experience a combination of the highest wind speeds and storm surge inundation, it can be challenging to separate the cause of loss, but assigning the damage to the correct sub-peril is necessary to assess the insured loss. Wind-related damage typically initiates at the roof and progresses downward, while coastal flood damage initiates at the ground and progresses to other parts of the building.

This building on Fort Myers Beach has a first floor that is about four feet above ground level, but the storm surge in this location was twelve feet, which led to storm surge damage on the first-floor structure and extensive interior losses. In addition to the surge damage, the second-floor wall siding and openings were severely damaged by high winds.

Combining the better building practices of higher first floor height and stronger foundation connections creates a much higher level of resilience to storm surge.

The buildings on the left have higher first-floor heights and stronger foundation connections, which left them undamaged by the storm surge while nearby homes were swept away (as shown by the piles left behind in the foreground, circled in red). The photo on the right shows piles left behind by a building with a lower first-floor height and poor foundation connections, which made it vulnerable to storm surge and led to the entire building being swept away.

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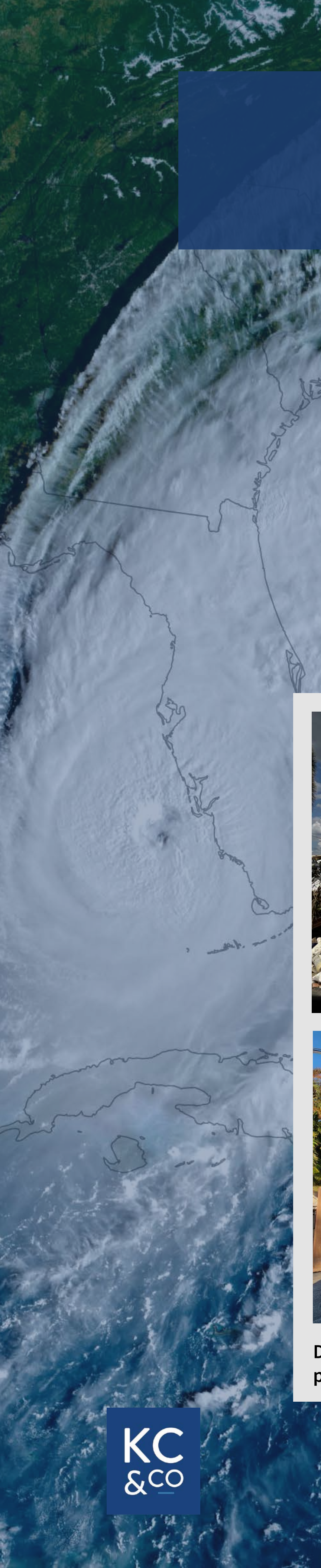
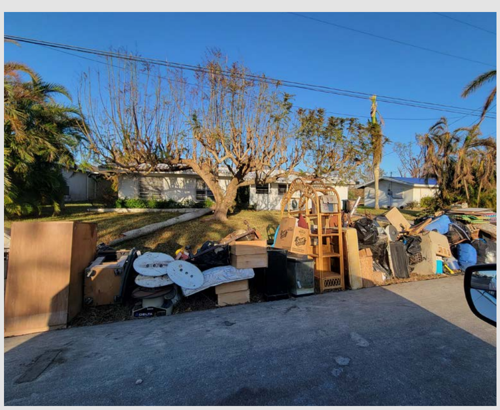


State of Recovery Six Months After Hurricane Ian

While repairs and rebuilding are well underway, it will take many more months to completely restore the areas most impacted by Hurricane Ian. The recovery and rebuilding process has been slow. Discussions with local contractors and builders revealed that while it has been relatively easy to get needed materials, labor is in short supply.

Debris removal is a large part of the initial recovery from a hurricane of Ian's magnitude. Because of the complete destruction of buildings and contents due to storm surge and high winds, even the debris removal process was not yet complete six months after the event. Many of the destroyed buildings—both residential and commercial—had not yet been demolished or cleared.

FEMA has estimated that Hurricane Ian created more than 32 million cubic yards of debris. At the time of the second survey, about 90 percent of the debris had been cleared from main roads in coastal areas, but side roads and many neighborhoods still had mountains of debris stacked along curb sides.



Debris and discarded interior contents pictured in October 2022

Debris and severely damaged buildings pictured in March 2023

As of March 2023, the most progress had been made to exterior components such as roofs and wall siding. Minor and moderate roof and siding damage had already been repaired in many cases, as well as some garage door damage. In addition, interior repairs had begun and even been completed in buildings with minor or moderate damage.

In buildings with severe damage, the process of demolition and rebuilding had begun in some cases; however, there are still many severely damaged buildings with no repair progress to date.

Between the two damage surveys, a home in Fort Myers pictured in October 2022 (left) and March 2023 (right) underwent garage door repairs and was cleared of debris.

A single-family home in St. James City on Pine Island pictured in October 2022 (left) and March 2023 (right) with no exterior repair progress.

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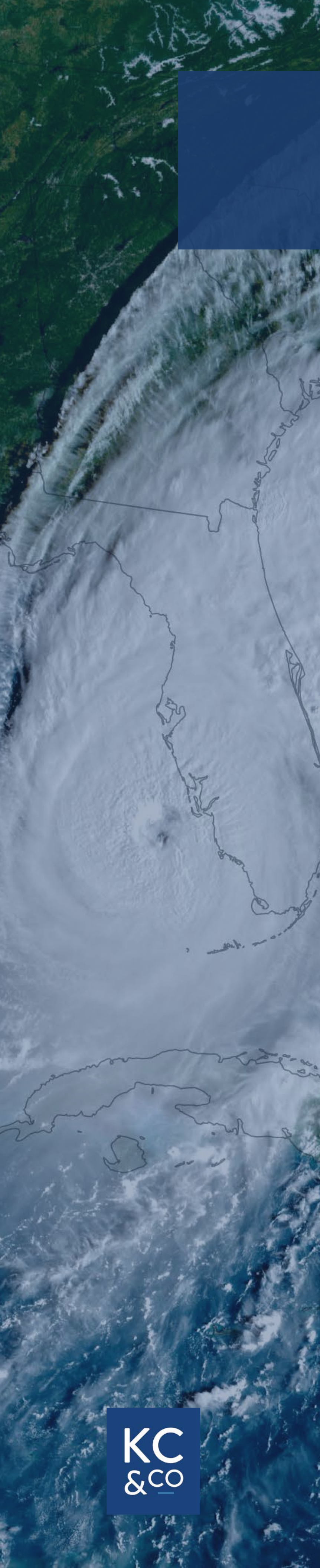

Summary

The 2022 North Atlantic Hurricane Season was remarkable for its mid-season lull and active second half, with ten of the season's fourteen named storms developing after September 1st. Despite the active second half, the season finished about average with respect to the number of storms. A high shear environment suppressed tropical development for much of the season, leading to fewer storms than predicted by NOAA despite the La Niña influence and warm SSTs.

Hurricane Ian was responsible for the vast majority of the 2022 hurricane season insured losses. Shortly following Hurricane Ian, KCC scientists and engineers conducted a post-event damage survey to assess the extent of damage by wind speed regime, followed by a second survey six months later to observe the state of repair.

The most extensive damage was observed in areas that experienced both peak winds and coastal flooding, such as Fort Myers Beach, Sanibel Island, Fort Myers, and Cape Coral, where damage was prevalent in nearly every building component.

Roof damage was especially pervasive at higher wind speeds, with metal roofs performing better than shingle or tile roofs. There were also a few instances of damage to older or poorly constructed metal roofs. Roof damage often leads to progressive damage.

Soffits were also damaged across all wind speeds. Soffit damage is not visible in aerial damage surveys, but it can lead to progressive interior damage and siding damage due to water infiltration, resulting in costly repairs.

Overall, residential, commercial, and industrial buildings in the impacted region performed as expected given the wind and surge conditions. In lower wind speed regimes, structural damage was typically limited to older structures. Damage patterns and mean damage ratios varied significantly between old and new buildings in similar wind speed regimes.

As of March 2023, debris removal and building repairs were underway in the impacted areas, but will take many more months to complete. KCC's damage survey team observed buildings in various states of repair—ranging from minor damage that has been fully repaired to completely destroyed buildings that have not yet been demolished or cleared.

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