2020 TROPICAL STORM SEASON OUTLOOK
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This report explores what the upcoming tropical storm season will bring, and how storm activities may impact supply chains, especially in light of the ongoing COVID-19 pandemic. The outlook analyzes concepts such as Sea Surface Temperatures (SSTs) and atmospheric components as drivers of the storm season, and uses metrics such as the Accumulated Cyclone Energy (ACE) to measure and quantify tropical storm activity this year. Our experts forecast that during the upcoming tropical storm season, companies should expect above normal activity in the Atlantic (Gulf of Mexico, Caribbean, and Atlantic). In the Pacific (East Pacific and West Pacific), companies should expect below normal activity, while in the Indian Ocean, companies should expect near normal activity.

Based on the history of tropical storm activity, the top three major ports with the highest risk are Port of Kaohsiung (Taiwan), Port of Hong Kong (China), and the Port of Shenzhen (China), while in the U.S. the port with the highest risk is Port of New Orleans. The top five major airports with the highest risk, based on tropical storm activity and freight volumes, are Hong Kong, Shanghai Pudong, Incheon, Taiwan, and Tokyo Narita. The report also identifies other key airports at high risk along the Atlantic including Miami, Charleston, and Dallas/Fort Worth as well as Mumbai and Kolkata along the Indian Ocean.

Data indicates that in the event of an approaching tropical storm, ports in the Caribbean, Gulf of Mexico, and the east coast of the U.S. usually suspend cargo operations for an average of 9 days while the ports in the Pacific and the Indian Ocean normally close for an average of 1-3 days and 1-2 days respectively. This report examines the manufacturing impact of such closures in the regions and the significance of the transportation hubs for industrial clusters.

The current pandemic has added more strain to cargo movement: Port productivity has slowed down due to lack of workforce availability amid government restrictions to curb the spread of COVID-19, while air freight movement has been heavily impacted by the global travel ban that has reduced the overall freight capacity in the market. As the tropical storm season approaches, organizations faced with balancing the impact of oncoming storms while attempting to maintain efforts to contain COVID-19 will need to prioritize resources and develop contingency plans in advance.
INTRODUCTION
The annual tropical storm season has begun with the recent passing of Severe Tropical Cyclone Harold, a category 5-equivalent cyclone on the Saffir–Simpson hurricane wind scale (SSHS), that battered the Pacific Islands in early April 2020 leaving trails of destruction. While this is only the first of potentially many storms to come this season, the added challenge posed by the ongoing pandemic will create further difficulties for areas prone to tropical storm activity.

In the wake of the COVID-19 pandemic, supply chains are more vulnerable than ever before to the upcoming tropical storm season. Transportation infrastructure and production facilities that have had to cope with restrictions imposed as a result of the outbreak will now have to grapple with the realities of the storm season and ensure that resources are allocated to mitigate risks arising from it. Productivity has been hit across many seaports due to the lack of available workforce amid restrictions imposed by local authorities to curb the spread of the virus, while global air freight operations have been impacted by reduced air travel that has taken freight capacity out of the market. Amid these challenges, supply chain professionals will have to plan in advance on how to address production delays and logistics bottlenecks and be prepared to make swift decisions during a crisis.

This report provides a comprehensive view of what to expect from the upcoming tropical storm season and shares insights on the disruptions and damages from past storms to help organizations prepare. Part 1 of the report outlines the long-term climatology of overall tropical storm risk. Part 2 examines the drivers of tropical storm activities and an explanation of the ACE system of risk assessment. Part 3 presents our predictions for the upcoming tropical storm season and themes to watch out for. Part 4 assesses the exposure of top ports, airports, and urban city centers to tropical storm activity and explains the methodology used to assess these risks. Part 5 looks at supply chain impacts of previous storms, specific issues faced by critical transportation hubs during past storms, and their current situation amid the COVID-19 outbreak. The report concludes with a set of recommendations on what organizations can do to assess their supply chain network’s exposure to the upcoming season and outlines measures they can adopt to minimize its impact.

"The COVID-19 pandemic has already tested and strained the boundaries of global transportation infrastructure and production facilities that will now have to prepare and react to the unpredictability of the storm season," said Shehrina Kamal, Product Director, Risk Monitoring for Resilience360.
Climatology is defined as weather conditions averaged over a period of time. The sections below outline the climatology of tropical systems - favored areas, length of the season, peak risk during the season - and examines how the climatology of tropical activity impacts supply chains.

TRADITIONAL METHOD OF MEASURING STORM ACTIVITY

A tropical season is defined as a period of time when tropical activity occurs. The seasons vary by area, which will be outlined in details below. One way to measure levels of tropical activity during a season is by the number of named storms. For example, the number of named storms last season in the Atlantic Basin was 18, compared to the normal of 12. The limitation of this method is that it does not take into account the duration or intensity of storms. In other words, a named storm can have a duration of 12 hours or 12 days; it is deemed as 1 storm. Instead, we introduce Accumulated Cyclone Energy (ACE) as a more robust method to quantify tropical storm activity.

ACCUMULATED CYCLONE ENERGY (ACE)

ACE is more frequently used by meteorologists and data scientists to quantify tropical storm activity. The ACE index accumulates storm wind data every 6 hours throughout the season and integrates overall storm frequency into the equation. As a result, total duration and intensity is covered and creates a long term measure of activity and risk.

Figure 1 depicts the seasonal ACE in the Atlantic Basin (Atlantic, Caribbean, and Gulf of Mexico) since 1979. This is the first year scientists were able to capture accurate satellite data of storms globally. Prior to this, there were likely some storms that were not counted. The ACE value (on the y-axis) is a sum of the wind speed for each storm and takes into account the number, strength, and duration of all tropical storms in a season. Because of this, the number assigned as the ACE value is a useful metric to assess infrastructure damage and monetary risk.

During the past 40 years, the seasonal average of ACE has been 108. The year with the highest ACE value at 245 was 2005, which featured highly impactful storms such as Katrina, Rita, and Wilma. In that year, there were nearly 4,000 fatalities and approximately USD 180 billion (EUR 166.4 billion) in damage. The year with the lowest ACE at 17 was 1983 with 22 fatalities and USD 3 billion (EUR 2.8 billion) in damage.

The past four years have been active with above normal ACE values. This is one of the only times in history that has featured this many years with above normal ACE values. The highest ACE year recently was 2017, which featured devastating storms such as Harvey, Irma, and Maria. Furthermore, each of the past 4 years has had a category 5 storm, which is unprecedented.
All in all, ACE gives a more quantitative view of how active or inactive a season is. It provides the best representation to determine the true level of risk and can also be used as a metric to forecast risk. Later in this report, the ACE value is forecasted for the Atlantic Basin.

**CLIMATOLOGY IN THE BASINS**

Figure 2 shows the tracks of all tropical storms across the globe over the past 40 years (1979 - 2019). This is an effective way to look at the frequency of storms and the areas that are most susceptible to tropical systems. The four basins that we will investigate in this section are highlighted.

Figures 3 through 6 outline ACE climatology throughout the year in each of the four main basins. In other words, they depict the historical distribution of activity throughout the season, i.e. when activity normally ramps up and ramps down along with peaks and extremes. On each chart, the middle 80 percent (light green), 50 percent (medium green), and 20 percent (dark green) of historical ACE values, determined by looking at the full 40-season history of ACE, are displayed along with the maximum (red dashed line) and minimum (blue dashed line) values. Each of the four graphs tells the story of the basin timeline, peak period of risk, and season longevity.

**INDIAN OCEAN**

The Indian Ocean tends to have less risk via tropical activity or lower ACE compared to other basins (West Pacific, East Pacific, and Atlantic). However, because many areas that surround the Indian Ocean are vulnerable (Bangladesh, parts of India, and east-central Africa), the impacts of storms making landfall tend to be greater and can have severe human and economic ramifications.
The Indian Ocean has two peaks during the season. The first is the May/June period while the second is late October through December.

**WEST PACIFIC**

The West Pacific is the world’s most active area for tropical cyclones. The season is lengthy and extends from April/May to November/December. The peak period is August through October. Unlike the Atlantic Basin, there is an early surge of activity in May and early June. In July, the risk of tropical storm formation increases and stays elevated through October before it begins to wane during the November/December period.

**THE ATLANTIC**

The Atlantic Basin is defined as the Atlantic, Caribbean, and the Gulf of Mexico. The season extends from June 1 through November 30. Storms in June and July are possible but rare. The core of the season tends to be from late August through early October with September being the peak month.
THE DRIVERS OF TROPICAL STORM SEASON
Whether a season is inactive or active, or in other words higher or lower risk, is largely determined by a combination of atmospheric and oceanic conditions. The role of the oceans is crucial as tropical systems get energy “locally” from the waters they travel over. The warmer sea surface temperatures (SSTs) are, the more energy tropical storms have to develop and strengthen.

Equally as important are the atmospheric conditions during a season or periods within a season. Active seasons tend to feature lower vertical wind shear (lighter winds from the surface into the upper atmosphere), and this causes less disruption for storm formation and storm strengthening. Stronger wind shear tends to “rip” storms apart and limits the ability for storms to form and gain strength. The jet stream pattern, i.e. whether a ridge of high pressure or a trough of low pressure is in place in a particular area, is also important in determining if conditions are favorable or unfavorable for storms.

Based upon these factors, each of which will be explained in detail below, the overall level of storm activity can be predicted, and an initial ACE value for the season can be assigned.

**SEA SURFACE TEMPERATURES (SSTs)**

An obvious starting point in this evaluation is sea surface temperatures (SSTs). Figure 7 depicts the SST anomalies in terms of degrees Celsius as of May 5, 2020. In the world map, areas that have a red or yellow shading represent waters that are above normal temperature (where normal is defined as the average temperature over the past 30 years); areas in blue shading feature below normal water temperatures. The majority of the global waters are warmer than normal. The relationship of SSTs and tropical storms is straightforward. The warmer SSTs are, the more risk there is of stronger storms - as tropical systems use the warm SSTs as fuel - and the higher the numbers of storms.

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<th>Sea</th>
<th>Description</th>
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<tr>
<td>Atlantic</td>
<td>SSTs in the vast majority of the formation zone (Gulf of Mexico, Caribbean, and Atlantic) are above normal</td>
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<tr>
<td>East Pacific</td>
<td>SSTs are close to normal</td>
</tr>
<tr>
<td>West Pacific</td>
<td>The West Pacific is a large area, but for the most part, SSTs are close to normal in the formation zones</td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>SSTs are warmer than normal</td>
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Ocean temperatures can change over time. Compared to the atmosphere, however, sea water changes are much slower. Air temperatures change daily, but ocean temperatures typically change over a period of months. The majority of the primary computer models indicate the same general tendencies in SST anomalies as we move toward the heart of the season this summer.

The current SST setup as well as the projection going forward is an item of concern for the Atlantic Basin and will have to be closely monitored as we approach the heart of the season. In the formation zones of the West Pacific and East Pacific, SSTs are more normal. The Indian Ocean is another “hotspot”, which will have to be closely monitored since when storms form, the warm ocean waters will provide more energy for intensification.
THE ATMOSPHERIC COMPONENT

At this point in the pre-season, details of specific storms cannot be determined. What can be analyzed, though, is the risk on a macroscale and the probabilities of whether an area will be at a higher or lower risk during the season. For example, we can assess whether the frequency of storms will be higher or lower than climatological normals in the various basins.

One of the primary drivers of determining favorable or unfavorable atmospheric conditions is whether an El Niño or La Niña will be in place in the Pacific Ocean. This phenomenon, commonly referred to as ENSO (El Niño Southern Oscillation), involves SSTs in the equatorial Pacific. A period when SSTs are warmer than normal is termed El Niño, while a period when SSTs are cooler than normal is termed La Niña.

WHY IS ENSO IMPORTANT?

This oscillation alters atmospheric wind conditions across much of the tropics depending upon how strong or weak the event is. Strictly speaking, changes in SSTs in the equatorial Pacific reverberate far away from that zone and impact jet stream patterns in the tropical Atlantic, Pacific, and Indian Oceans.

El Niño events (a period of warmer than normal SSTs in the equatorial Pacific) tend to, on average, end up suppressing tropical storm activity in the Atlantic Basin and enhancing activity in the west Pacific. Warm episodes (El Niño events) strengthen the subtropical jet, which forms in the Pacific but eventually travels across the Gulf of Mexico, Caribbean, and tropical Atlantic. The strong jet increases wind shear, and this rips storms, or storms before they form, apart and, in most cases, produces seasons that are less active in the Atlantic.

Figure 8 depicts the ACE value for every year in the Atlantic from 1979 to 2019. Years when an El Niño was present are shaded in red while the blue years show that a La Niña event was in place. As can be seen, many years feature neutral conditions. Most seasons, but not all, that feature an El Niño event tend to be less active. Most seasons, but not all, that feature a La Niña event tend to be more active. When the averages (the horizontal lines parallel to the x-axis in Figure 8) are plotted, the story is clear. Compared to the long-term ACE climatological normal of 108, the average of El Niño years is around 60 while the average of the La Niña years is nearly 140. Hence, there is a much higher risk of tropical activity during seasons which have a La Niña event. As will be discussed later, computer models are indicating that a La Niña event is a distinct possibility by the late summer/early fall, which is the peak of the season.
In the west Pacific, the most active tropical zone on the globe, the correlation is the opposite. El Niño years tend to feature more active (higher risk) conditions while La Niña years tend to feature a higher incidence of inactive years (lower risk). Much like the Atlantic, the correlation does not occur every year, but there is a clear bias of more or less risk when an El Niño or a La Niña is in place. With a La Niña event looking more likely, this would reduce the overall risk of tropical systems during the upcoming season.

This year, SSTs in the equatorial Pacific are near normal, as depicted in Figure 7. There are increasing signals that water temperatures in the equatorial Pacific will be cooling during the summer and fall. Namely, there will be a transition to a La Niña event. Whether we specifically reach a La Niña event during the upcoming season is debatable. At the very least, this year looks to feature neutral to La Niña conditions. One possible scenario is that the season starts out with neutral conditions (June/July) and ends with La Niña conditions (September/October).

From an atmospheric standpoint, the season looks to feature more of a La Niña flavor than an El Niño one. As a result, the risk in the two primary basins that most impact global supply chains are opposite from each other. The Atlantic Basin has an increased risk of activity, while the West Pacific has a decreased risk.
THE 2020 FORECAST
INDIAN OCEAN - EQUAL RISK

Risk drivers: Warm Sea Surface Temperatures and trending towards La Niña.

In the Indian Ocean, the signals are mixed. The relationship between an El Niño or a La Niña and tropical activity in this region is not as straightforward. SSTs, though, are very warm across much of the Indian Ocean. Combining all the indicators, our forecast for the Indian Ocean is for near-normal tropical activity during the upcoming season.

WEST PACIFIC AND EAST PACIFIC - DECREASED RISK

Risk drivers: Near-normal Sea Surface Temperatures and trending towards La Niña.

In the Pacific, the combination of more neutral water temperatures and an easing toward La Niña reduces the odds of activity this season. Hence, our initial forecast for both the East Pacific and West Pacific is for below normal ACE values. Like the Atlantic, this does not imply that an individual storm cannot cause major disruptions in the supply chain if it impacts a vulnerable area. Rather, it shows us the overall level of risk for the season is lower than normal.

ATLANTIC - INCREASED RISK

Risk Drivers: Warm Sea Surface Temperatures and trending towards La Niña.

The combination of ocean temperatures (warm SSTs) and atmospheric conditions (a trend toward La Niña) places the highest risk this year in the Atlantic Basin. As a result, we are forecasting above normal ACE values for the upcoming season in the Atlantic. Based on current expectations, the forecast range is 125-150. If La Niña evolves more rapidly, this forecast range would increase and vice versa. Figure 10 below shows the forecast for the upcoming season.

It is important to note that while we are forecasting an active season in the Atlantic Basin, this does not tell us anything about individual storms and how they may impact specific entities in the supply chain. Those factors will be addressed by the Riskpulse and R360 teams on a regular basis throughout the season. There have been inactive seasons wherein one storm had major ramifications on people, infrastructure, and logistics. Hurricane Andrew in 1992 is a prime example of this. Overall, there will be higher risk of supply chain disruptions this season than the climatological norm in the Atlantic Basin.
THE RISK LIST: PORTS, AIRPORTS AND CITIES
As part of this report, one of the most unique initiatives undertaken by our team has been to quantify the level of storm risk in key transportation hubs as well as urban areas. This allows us to effectively understand the exposure of each location based on tropical storm activity and help organizations assess where to focus their mitigation efforts.

THE METHODOLOGY

We analyzed the top 25 global ports (in terms of container volume) and airports (in terms of tonnage of cargo) and determined their precise locations via latitude/longitude. Then we integrated the past 50 years of tropical storm activity data and calculated the frequency of tropical systems that tracked near these locations.

By combining these two elements, we were able to determine the frequency that storms moved near a specific location. Using this historical methodology, we calculated the risk of each port or airport and ranked them. Here are the top 10 lists below.

PORTS

The list includes the top 10 ports with the highest risk on a global basis. The port with the highest risk is Port of Kaohsiung in Taiwan, which is located in the southern portion of the island. The next 7 ports at the highest risk are all located in east Asia, in particular China and South Korea. The top 8 are in the West Pacific, which, of course, is the most active area for tropical storms on the globe. The final 2 that made the list are Colombo in Sri Lanka and Laem Chabang in Thailand.

What about the ports in the U.S.? Since our study took into account the top 25 global ports (based on container volume), none of the ports along the Gulf of Mexico or East Coast made the list. Of the ports specifically in the U.S., we used the same methodology as the global ports and determined the U.S. ports that are at highest risk. Below is a list of the top 5 ports in terms of tropical storm risk. The U.S. port with the highest risk is New Orleans followed by Houston.

Top 10 Ports
TC Risk
1. Kaohsiung, Taiwan
2. Hong Kong, China
3. Shenzhen, China
4. Guangzhou, China
5. Xiamen, China
6. Busan, South Korea
7. Ningbo-Zhoushan, China
8. Shanghai, China
9. Colombo, Sri Lanka
10. Laem Chabang, Thailand

Figure 11: Top 10 Global Ports at Risk of Tropical Cyclones. Source: Riskpulse
CARGO AIRPORTS

Figure 13 portrays the top 10 airports, based on cargo, at the highest risk of tropical storm activity on a global basis. Of the top 25 largest cargo airports globally, the hub with the highest risk is Hong Kong. As one would expect, the majority of the airports at highest risk are located in the west Pacific. One U.S. airport, namely Miami International Airport, made the top list at number 7.

Top 5 U.S. Ports
TC Risk
1. New Orleans, LA
2. Houston, TX
3. Mobile, AL
4. Savannah, GA
5. Jacksonville, FL

Top 10 Cargo Airports
TC Risk
1. Hong Kong
2. Shanghai Pudong
3. Incheon
4. Taiwan Taoyuan
5. Tokyo Narita
6. Singapore Changi
7. Miami, FL, U.S.
8. Guangzhou Bai Yun
9. Tokyo Haneda
10. Shenzhen
CITIES & URBAN AREAS

Finally, Figure 14 portrays the top 10 cities at the highest risk of tropical storm activity. Our analysis included all cities with a population over 1 million people, which is around 540 cities. Unlike the port and airport lists above, the risk analysis for the major cities includes a wider geographical area for each city and urban area.

Manila in the Philippines is the city with the highest tropical storm risk. The bulk of the top 10 cities are in China, Japan, and the Koreas. Two cities in India made the list with the tenth spot being Houston, Texas.

Top 10 Global Cities TC Risk

1. Manila, Philippines
2. Hong Kong, China
3. Xiamen, China
4. Tokyo, Japan
5. Busan, South Korea
6. Shanghai, China
7. Kolkata, India
8. Chennai, India
9. Ho Chi Minh, Vietnam
10. Houston, TX, U.S.
SUPPLY CHAIN IMPACTS OF TROPICAL STORMS
Tropical storms and the associated impacts that occur in the aftermath of a storm’s passage have devastating effects on international supply chains. Massive airline cancellations, airport and cargo port closures as well as shipment delays create a ripple effect of disruptions down to multi-tiers. This section examines past storms and their impact on ports and airports across three regions: the Indian Ocean, the Pacific, and the Atlantic.

**INDIAN OCEAN**

Based on the past cyclone records, Resilience360 has identified three common cyclone trajectories. The first cyclone path normally develops in the Bay of Bengal, curves towards Indian northeast coastal states and proceeds towards Bangladesh southern delta. On the second path, a cyclone would usually head directly to India’s east coast such as Andhra Pradesh and Orissa States while on the third projected path, a cyclone crosses the Arabian Sea, while affecting operations along the northwestern coast of India.

Precedents indicate that between 2000 and 2019, more than 80 percent of cyclones in the North Indian Ocean with wind speed equivalent strength of a category 3 hurricane or higher had made landfall on the east coast of India (Bay of Bengal), making air and sea cargo hubs higher risk. Figure 15 shows ports from India’s east and west coasts as well as the major ports from Bangladesh that had been affected by various cyclones in the past.

**SERIES OF PORT CLOSURES FROM CYCLONES (2017-2019)**

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<tr>
<th>Ports in South Asia</th>
<th>Port closure period in no. of days</th>
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<td>Port of Mongla, Bangladesh</td>
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<td>Port of Payra, Bangladesh</td>
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<td>Port of Paradip, India</td>
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<td>Port of Haldia, India</td>
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<td>Port of Kolkata, India</td>
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<td>Port of Dhamra, India</td>
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<td>Port of Gopalpur, India</td>
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![Figure 15: Duration of Port Closures in the Indian Ocean from the Impact of Cyclones between 2017-2019. Source: Resilience360](image)

In 2019, back to back cyclones – Vayu and Fani – caused massive port closures along India’s east coast (Bay of Bengal) and northwestern coastline of Gujarat State (Arabian Sea). According to Resilience360 data, the average port closure for Indian ports in the Arabian Sea for a category 3 equivalent cyclone is around 3.5 days, and the average port closure for ports along the Bay of Bengal for a category 2 and above equivalent cyclone is about 1.5 day. The average berthing delay in the aftermath of a cyclone is about 24 hours or more at the aforementioned ports.
PORTS AT RISK OF HIGH IMPACT IN THE INDIAN OCEAN

With the exception of Port Colombo, most of the ports in the Indian Ocean have not made it into the aforementioned list of ports with a high exposure to cyclones. The list of ports that are most at risk took into account the top 25 ports globally, and many of the ports along the Indian Ocean do not make the cut in terms of container volumes. Nevertheless, due to their proximity to key manufacturing hubs in the region, these ports have been identified to be at high impact, albeit at medium risk, of cyclonic activities.

The Port of Mundra and Port of Pipavav are the two container gateways for India’s west coast due to the presence of automotive, engineering, chemical, and health care industries in the region that use these ports for both import and exports. The Port of Mundra is India’s largest commercial port that handles more than 100 mega metric tons (mt) of cargo and serves as a key logistics gateway for cargo transport to the landlocked northwest hinterland of India, while the latter is mainly operated by Maersk subsidiary APM Terminals on the West Coast of India for containers, bulk, and liquid cargo. Both ports are prone to cyclones, as demonstrated by Vayu in 2019 when it battered Gujarat State, prompting closures.

However, severe cargo congestion has been reported at the Port of Mundra since early March as trucks were halted at the port due to COVID-19 pandemic restrictions. Clearance of import containers were taking longer to process by importers and custom house agents amid the ongoing nationwide lockdown in India that is expected to be lifted on May 17. To ensure the possible delays in the delivery of cargoes and other port-related services to not affect its commercial contracts with the port users, the port declared force majeure on March 26 for an indefinite period. The start of the cyclone season in the Indian Ocean may exacerbate the current congestion issue at the Port of Mundra.

The ports of Kolkata and Haldia in India’s east coast in the West Bengal State are also regarded at risk of annual cyclone disruption. Both ports’ cargo handling were suspended for 2 days during Cyclone Fani’s passage in 2019, with 11 ships berthed at Kolkata and 16 at Haldia, while 12 ships bound for both ports were stranded at sea. Kolkata port’s main export and import includes automobiles, motorcycles, and general industrial cargo including iron ore, granite, coal, fertilizers, petroleum products, and containers; the port handled 63.763 mt of traffic in FY 2018-19. While there has not been any reports of COVID-19 related disruptions at Kolkata, Haldia Port, which handles the import of petroleum, chemicals and export of coal, iron ore, and steel with 45.2 mt of cargo traffic in 2018-19, suspended its dry bulk vessel operations for a few days for a deep cleansing operation at the port site after an employee was tested positive for the virus in April.

The Port of Chittagong is Bangladesh’s busiest port that handles bulk cargo such as rice, wheat, salt, crude oil, cement clinkers, and industrial raw materials and is vulnerable to the impact of severe cyclone passages from the Bay of Bengal typically around May to June period, which coincides with the Islamic holy month of Ramadan that is celebrated in the country annually. The port is at its busiest for import and export activities during this time, thus, severe vessels’ congestion amid the lockdown combined with the start of the cyclone season is highly likely to disrupt the port’s capacity.

Cyclone Fani in May 2019 caused significant congestion at the port that lasted until August as around 111 import carrying ships had to wait for an average 8 days for an available berth. The port has already been experiencing significant congestion and delays in import clearing with an average of 16 days for vessels to berth due to the lockdown measures imposed by Bangladeshi authorities to combat the COVID-19 outbreak. Thus, any intense cyclonic activity in the region is likely to exacerbate the situation.
While there has not been any major disruptions from cyclones at the Port of Colombo in Sri Lanka in recent years, its strategic location in the Indian Ocean serves as an important terminal in South Asia for transhipment of container traffic. While the ongoing COVID-19 related curfews are in place in the Colombo district, there has not been any major disruption to the port activities. The port may, however, face impacts from cyclones that normally form in the Bay of Bengal with a northwest track towards India’s east coast are likely to have an impact on the port.

**AIRPORTS AT RISK OF HIGH IMPACT IN THE INDIAN OCEAN**

Below are the top five airports that are located in India’s east and west coastal regions as well as in Sri Lanka, and are considered vulnerable to high impacts from the destruction of annual cyclones.

**Chhatrapati Shivaji International Airport (BOM)** in India serves the Mumbai Metropolitan area and is regarded as the second busiest airport for cargo traffic in India (963.46 thousand metric tons in 2019) and 14th busiest for total passenger traffic in Asia. Strategically located on India’s west coast, Mumbai is the largest Air Cargo Complex in India in terms of volume of cargo handled, value of cargo, documents filed, and revenue collected with export flights mainly to the U.S., Germany, South Africa, France, and the United Kingdom. Although the current COVID-19 lockdown had created a huge cargo backlog of import shipments such as non-essential commodities like engineering goods and electronics, its proximity to the Arabian Sea, which lies on the cyclone path, exposes it to possible disruptions to air freight operations; Cyclone Vayu affected 400 flights at BOM in 2019.

**Sardar Vallabhbhai Patel International Airport (AMD)**, located in Ahmedabad in Gujarat State near Mumbai, is the state’s only airport that caters to air freight. Due to a spike in exports of Indian pharma products and other perishable goods via AMD overseas, the airport ranked as the sixth busiest air cargo hub in India with 101.73 thousand metric tons in 2019. With an increased availability of commercial flights along with three fixed freighters, AMD has grown popular amongst local chemical, pharma, textiles, apparel and engineering manufacturers to ship exports from Ahmedabad instead of Mumbai. This is largely due to cost-savings as shippers are now able to save time and cost by using AMD, when previously, road transport cost to Mumbai from Ahmedabad had to be considered when shipping from BOM. There have been no reports of COVID-19 related disruptions at AMD at all 11 airports in the coastal state of Gujarat, though all are prone to damage from severe cyclones. Although the impact of Cyclone Vayu in 2019 was minor, over 400 commercial flights were cancelled and operations were suspended at five airports in Gujarat.

**Chennai International Airport (MAA)** serves Chennai and other metropolitan areas of Tamil Nadu State in India. Is it the third busiest airport in India with 411.61 thousand mt in 2019 and provides critical air cargo capacity out of the country, after Delhi and Mumbai airports, with its connecting flights to Asia, Europe, and the Middle East. Manufacturing sectors in Chennai include automobile, hardware manufacturing, petrochemicals, textiles, and apparels. Serving as an important hub to ship critical cargo from these industries, the airport is situated on India’s east coast and is on the path of common cyclone tracks as well as prone to other natural disasters. MAA has faced intermittent disruptions from a series of cyclones in the past such as Cyclone Vardah in 2016 and Gaja in 2018. Despite the COVID-19 lockdown, MAA has reportedly handled over 8,000 mt of cargo for essential and non-essential goods in March and April for domestic and oversea destinations.
Netaji Subhas Chandra Bose International Airport (CCU) serves the Kolkata metropolitan area in West Bengal State, on the east coast of India. Automobile parts continue to be the largest bulk of air cargo movement from Kolkata to other countries such as China, Hong Kong, Qatar, and Bangladesh. This is because the state is dominated by Original Equipment Manufacturers (OEMs) and auto components makers as raw materials such as iron and steel are easily accessible in the state. In 2019, CCU handled 155.23 thousand mt of cargo as the fifth busiest air cargo hub of India. As it lies on one of the common trajectories of cyclones in the region, CCU is prone to disruptions. Cyclone Fani and Bulbul, both in 2019, have proven that any passage of cyclones in the Bay of Bengal is bound to disrupt airline operations in the region. Despite the current lockdown imposed by authorities as a response to the COVID-19 outbreak, the airport remains functional for air freight.

Bandaranaike International Airport (CMB), based in Colombo, Sri Lanka, handled 280 million metric tons of cargo in 2018, with freight shipments having grown at eight percent in the past five years. Due to the growing capacity, the government has approved to build another air cargo terminal in 2019. CMB handles various types of goods, including dangerous, valuable, and perishable cargoes, as well as outsized and heavy cargo. Similar to the Port of Colombo, its strategic position in the Bay of Bengal exposes it to cyclonic activities. Although inbound passenger flights were suspended due to the COVID-19 pandemic for about a month at CMB, air freight remained functional with no major disruption.

THE PACIFIC

Similar to the Indian Ocean, there are three common trajectories for typhoon tracks in the Pacific. The first path normally curves towards the East China Sea brushing past the southern tip of the Korean peninsula, subsequently affecting the Japanese islands of Kyushu, Shikoku, and the eastern coast of Honshu. The second path either cuts across Taiwan or sweeps past the island and usually proceeds towards China's southeast or eastern provinces such as Hong Kong, Guangdong, Fujian, Jiangxi, Zhejiang, and Jiangsu. The last typhoon path moves lower than the first two, passes through the Philippines' northern island, and heads towards central Vietnam before moving further inland to the rest of Southeast Asia.

According to the world's top cargo output in 2019, 15 Chinese ports ranked the highest out of the top 20 global ports. Based on Resilience360 data, the ports in China, Taiwan, Japan, and South Korea have been the most impacted by various typhoons in the past three years. An average port closure period resulting from typhoons ranges from 1-3 days. According to the data, there were more severe tropical storms (category 2-equivalent hurricane and above) that impacted the ports in Pacific than in the Atlantic and Indian Oceans, confirming the list of ports highly exposed in part 4 of this report.
PORTS AT RISK OF HIGH IMPACT IN THE PACIFIC

The higher frequency of typhoons in the Pacific means that the following ports are at risk of high impact based on their locations and cargo throughput.

The **Port of Kaohsiung** is regarded as Taiwan’s largest port, handling various bulk cargo for export and import, with a strong support for the petrochemical industry. The port’s strategic location in the Pacific Ocean makes it exposed to typhoon disruption. Normally, the port is the first to bear the impact of storms before it continues to China or Japan. Tropical Storm Danas alone caused a 2-day port closure in July 2019; in 2016, 10 berthed vessels at the port broke loose from their moorings amid high seas caused by Typhoon Meranti.

China’s southeastern ports – **Hong Kong, Shenzhen, Guangzhou, and Xiamen** – have been considered some of the world’s busiest ports in 2019. The Port of Hong Kong is commonly regarded as an economic gateway to mainland China that handled up to 19.8 million in TEUs, while the Port of Guangzhou (18.9 million in TEUs), Shenzhen (24.0 million in TEUs), and Xiamen (9.6 million in TEUs) also play critical roles in connecting cargo from the region to the rest of the world. Despite their importance for global ocean freight movement, the ports are prone to typhoons coming from the South China Sea. Category 5-equivalent Typhoon Mangkhut in September 2018 took this route, after making an initial landfall in the Philippines, and battered China’s southern area, prompting massive port closures and berthing delays. COVID-19 restrictions have not impacted these ports significantly at the time of writing, and they remain fully operational, with an average vessel berthing delay of 0.5 to 1 day.
Similarly, **Port of Busan** in South Korea, considered the fifth busiest cargo port in the world with a total volume of 19.9 million TEUs in 2019, is also at risk from typhoons that track towards Japan via the East China Sea route. While the port is less likely to face a direct impact from typhoons, as the majority of storms generally make landfall in Japan, the outer wind bands of the storm tend to affect the Korean peninsula due to its proximity to Japan. An average port closure lasts about 1–3 days depending on the typhoon’s wind intensity. While the port’s situation is currently normal with an average berthing delay of 12 hours, Busan experienced severe congestion from increased transshipment volumes that were diverted from Chinese ports in early March when most parts of China were still under the COVID-19 lockdown, causing schedule havoc for some carriers. Any restrictions further imposed due to a potential resurgence of COVID-19 infections during the typhoon season may therefore have an adverse impact on the port’s performance.

Lastly, **Port of Tokyo** is Japan’s busiest seaport and a major gateway for linking land and sea transport of goods from the Tohoku region, where a large cluster of manufacturers from the renewable energy, semiconductor, automobile, and medical equipment manufacturing industries are based. In 2019, the port handled a cargo volume of 4.6 million TEUs. Despite its major role in facilitating the movement of ocean freight and the current state of emergency in place in Tokyo due to the COVID-19 pandemic, operations at the port remain normal. However, as the typhoon season unfolds in May, the port is vulnerable to storm surges and torrential rain from storms, as it is situated on the eastern coastline of Honshu, which is along the path of typhoons. A category 5-equivalent Typhoon Hagibis made landfall in the Greater Tokyo area in October 2019, which resulted in a series of port closures in the Tokyo Bay. The inclement weather caused schedule disruptions for international carriers like Maersk, Hapag Lloyd, and Ocean Network Express as services were delayed for 2 to 5 days.

**AIRPORTS AT RISK OF HIGH IMPACT IN THE PACIFIC**

Below are the top five Asian airports that are at risk of disruption, both in terms of highest exposure as outlined in Part 4 as well as from cargo transport relevance, from typhoons as they are located on the trajectory of common typhoon paths.

**Hong Kong International Airport (HKG)** is the world’s busiest airport as it handled 5.1 million tons of total cargo throughput in 2018, which accounted for 42 percent of the total value of Hong Kong's external trade. According to data from CAPA/OAG, HKG suffered a significant decline in transshipments from January 2020 due to the widespread travel ban imposed as a result of the COVID-19 pandemic. The airport frequently faces severe tropical storms as it is situated along one of the common storm tracks. In 2018, at least 1,200 flights were cancelled at HKIA due to Typhoon Mangkhut. The airport operated two runways to clear the backlogs on time. Any inclement weather may completely halt airfreight operations at HKG, having been already impacted by the reduced air cargo capacity due to the global travel ban.

**Shanghai Pudong International Airport (PVG)** is the world’s third busiest hub for air cargo after HKG, with a record of handling 3,768,573 tons of total cargo in 2018. The current pandemic has caused a dip in air freight volumes at PVG from January until March. According to data from CAPA/OAG, volumes of air cargo show an upward trajectory from April after the lockdowns were lifted in China. The thriving manufacturing sectors in Shanghai including healthcare, information technology, automobile, and chemical rely on PVG for outbound shipments. However, frequent mass flight cancellations due to typhoons have been reported in the past as it is also located on the common storm path. In 2019, 1,160 flights were cancelled due to Typhoon Lekima affecting major airlines such as Air China Ltd., China Eastern Airlines Corp., and China Southern Airlines Co.
Incheon International Airport (ICN) serves Seoul and is South Korea’s largest airport for both cargo and passengers. Similar to PVG, the air cargo volumes and capacity at ICN dropped significantly from January and flattened between March and April. Volumes for air cargo are showing an upward trajectory in the coming months as South Korea returns largely to normal with the COVID-19 outbreak considered mostly under control in the country. Its strategic location in the Korean peninsula makes it vulnerable for typhoons from the East China Sea. Strong winds from Typhoon Lingling in 2019 prompted road closures including bridges that connect to ICN, while 120 flights were cancelled.

Taiwan International Airport (TPE) was ranked the eighth busiest airport globally for air freight in 2018, with a total air cargo throughput of 2,322,823 tons and a record of 2.3 billion kg of weight. It provides cargo services for over 30 airlines, connecting to Asia, Middle East, and Europe. Recently, China Airlines has been aiming to increase its pharma volumes via TPE by standardizing pharma handling across its network. Due to its large trading network with China, TPE felt the immediate impact of the global pandemic, with a sharp drop in capacity from mid January; the volume is normally split equally between passenger and all-freight services. Moreover, located between the East and the South China Sea, TPE is exposed to frequent typhoons that either head to China’s east coast or track northwards across Japan. Typhoon Faxai in 2019 caused 450 flight cancellation at TPE when the typhoon steered towards Japan.

Tokyo Narita International Airport (NRT) serves the Greater Tokyo Area of Japan and has been ranked as the world’s ninth top air cargo hub with a cargo volume of 2,261,008 tons, catering to medical cargo and perishable goods with appropriate temperature management. Its main market is China and the U.S.. While the airport has not had any temporary closures in recent years, mass flight cancellations are common prior to an approaching storm. For example, back to back typhoons – Faxai and Hagibis – in September and October 2019 caused 100 flight cancellations at NRT while the national carrier, Japan Airlines, cancelled more than 90 percent of domestic flights to and from Tokyo’s Haneda and Narita airports. Similar to China and Korea, NRT experienced a sharp decline in cargo volume from January as a result of the COVID-19 outbreak. Cargo carried by freighters from NRT is reportedly two and a half times the volume carried on passenger planes.

THE ATLANTIC

Hurricanes typically follow one of four common paths. The first trajectory crosses the western Caribbean Islands before making its way through the Gulf of Mexico, while the second trajectory normally tracks further northwards across the Caribbean Islands towards southern Florida. In the third path, hurricanes can take a direct passage towards the U.S. coastline towards Florida, while in the fourth possibility follow a path further northwards along the U.S. east coast.

Based on data between 2017 and 2019, the severity of the hurricanes that impacted the ports along the Atlantic were higher in terms of their wind intensity compared to the storms in the Indian Ocean and the Pacific. For example, Hurricanes Harvey, Maria, Florence, Michael and Dorian all had category 4 and 5 equivalent wind speed, the highest in the five-tier Saffir–Simpson hurricane wind scale. Due to the severity of the hurricanes, the ports in the Caribbean, Gulf of Mexico and the east coast of the U.S. usually suspend cargo operations for an average of 9 days while the ports in the Pacific and the Indian Ocean normally close for an average of 1-3 days and 1-2 days respectively.
Resilience360 records between 2017 and 2019 show that ports along the western Pacific Ocean, particularly the U.S. west coast, did not experience any significant disruptions as the majority of the hurricanes were concentrated in the North Atlantic Ocean. As Figure 17 shows, the longest port closure in the U.S. was recorded in September 2018 with the maximum closure period of 14 days at the Port of Morehead (North Carolina) due to Hurricane Florence. The ports along the U.S. east coast – Wilmington (Delaware), Baltimore (Maryland), Norfolk (Virginia), Charleston (South Carolina), and Savannah (Georgia) – were shut for an average of 9 days. Extended closure periods mean that knock-on effects, such as berthing and yard congestion, port call omissions and diversions, as well as missed vessel connections are likely, subsequently delaying import, export, and transit shipments, raising costs and prolonging shipping times for a few weeks even after the storm had dissipated.

**SERIES OF PORT CLOSURES FROM HURRICANES (2017-2019)**

![Graph showing port closures](image)

*Figure 17: Duration of Port Closures in the Atlantic from the Impact of Hurricanes between 2017-2019. Source: Resilience360*
PORTS AT RISK OF HIGH IMPACT IN THE ATLANTIC

Based on the importance of cargo throughput and their locations that lie on the common projected paths of hurricanes, the following ports, in no particular order, are at risk of high impact from hurricane disasters.

As highlighted in Figure 17, most of these ports have faced temporary closures of around 10 days during previous hurricanes. The ports of New Orleans and Houston are important container gateways in the Gulf of Mexico for petrochemical facilities located near Lake Charles in western Louisiana and near the Mississippi River in Baton Rouge, Geismar, and Plaquemine. According to industry reports, cargo volumes through the U.S. Gulf ports increased 17 percent year over year to 579,823 loaded TEU in September 2019 due to the rising number of Asian services to the Gulf. The growth outpaced both the U.S. east coast and the west coast, as the east coast port volumes grew 6.4 percent while the west coast volumes fell 1.5 percent in throughput in 2019.

Nevertheless, the current COVID-19 pandemic and the resulting drop in market demands have caused a reduction in cargo volumes for ports across the U.S. This has been exacerbated by blank sailings by ocean carriers as well as the ongoing statewide lockdowns in the U.S. that has reduced consumer spending. At the time of writing, the Port of Houston has experienced seven blank sailings on Asian services in March with a few more expected in May. In March, the port briefly shut down all shipping traffic after a worker tested positive for the virus. As precautionary measures, both ports have implemented maritime advisories against inbound vessels. With port productivity at risk due to the COVID-19 pandemic, oncoming storm systems may prove to be an additional challenge.

As hurricane season draws near, both ports are vulnerable to disruptions. Hurricane Harvey took this path in 2017, crossing the western Caribbean and Yucatán Peninsula before making its way through the Gulf and making landfall in Texas. Port of Houston, which handles about 70 percent of the Gulf container cargo, resumed activities about a week after the hurricane, while the Houston Ship Channel was closed for 5 days causing jet fuel and gasoline shortages. There were also challenges to dredging activities at the channel due to the catastrophic flooding and residual debris left behind by the hurricane. Cargo vessels faced challenges navigating as there was no proper depth due to the deposited silt, which subsequently affected the vessels' cargo loading capacity and increased costs.

In the U.S. east coast, the ports of Savannah, Charleston, and Morehead are also susceptible to the passage of hurricanes, which may affect operations at manufacturing and distribution facilities in northwestern Florida, Georgia, and Alabama and compromise aerospace, automotive, and industrial engineering supply chains, of which there is a strong presence in these states.

The Port of Savannah in Georgia is the second largest port in the east coast in terms of TEU throughput and specializes in the handling of containers, reefer, breakbulk, and roll-on/roll-off cargo that include forest and wood products; automotive and heavy equipment; steel; heavy-lift cargo; and project shipments. The port has been negatively impacted by the COVID-19 pandemic, as it moved only 335,789 TEUs in March, which was a decrease of 74,537 TEUs compared to the same month last year. As part of its COVID-19 safety measures, the port closed its gates to truck drivers on all Saturdays in April causing a slow cargo flow. The reduction in trucking hours is expected to have a knock-on effect in cargo movement in the coming months, and as the hurricane season in North America normally peaks in August, any inclement weather may further hamper the port’s cargo volumes.

The looming hurricane threat also applies to the ports of Charleston and Morehead City in South and North Carolina, which are already experiencing blank sailings by carriers due to the pandemic. Charleston is the fourth largest port in the east coast, handling automobiles and locomotives as well as
non-containerized goods and project cargo, while Morehead City primarily handles bulk and break bulk cargo.

Puerto Rico has a large presence of life sciences and healthcare companies as well as marine oil terminals. Despite the country’s strategic location for import and export activities, it sits on the collective path of hurricanes that normally develop from the central or eastern Atlantic Ocean. Both Hurricane Maria (2017) and Hurricane Dorian (2019) followed this track. The devastating impact of Maria meant that it took almost a month for the Puerto Rican ports, including the Port of San Juan, to reopen while causing severe shortages in diesel and gasoline. At present, there has not been any reports of COVID-19 related disruption at any of the terminals in the territory. Nevertheless, as hurricane season approaches, organizations faced with balancing the impact of hurricanes while attempting to maintain efforts to contain COVID-19 will need to prioritize resources and develop contingency plans in advance.

**AIRPORTS AT RISK OF HIGH IMPACT IN THE ATLANTIC**

A number of airports are at high risk of impact, based on cargo movement and hurricane trajectories.

**Miami International Airport (MIA)** serves Florida and handles 79 percent of all air imports from and 77 percent of all exports to Central and South America. MIA functions as a hub to facilitate the movement of perishable products, hi-tech commodities, telecommunications equipment, textiles, pharmaceuticals, and industrial machinery. Due to a large presence of medical device makers and their distribution centers in Florida, MIA has been designated a Pharma Hub Airport in the U.S., the second one in the world after Brussels Airport. As a result, Florida remains a concern during the annual hurricane season, as three out of the four common trajectories have the potential to impact the state’s east or west coasts, heightening the risk of disruption for air freight. The current pandemic has added more strain to cargo movement, as the U.S. government has suspended flights from international and domestic COVID-19 hotspots to Miami International Airport.

**Orlando International Airport (MCO)**, also located in Florida, serves the Americas and the European market. The airport’s strategic location in proximity to several manufacturing clusters including life sciences and health care, technology, and aerospace engineering implies that it can be an important alternative transport hub in the event that capacity in and out of MIA is unavailable. Nonetheless, the state’s unique geographic position makes it particularly vulnerable to impacts from passing storms, which makes MCO also at risk of disruption.

**Charleston International Airport (CHS)**, located in South Carolina and just above Florida, is also prone to intermittent disruptions involving closures and mass flight cancellations during a storm’s passage. The air freight market in CHS has significantly increased due to the state’s growing automotive industry, with the presence of over 60 global automotive OEM companies and component manufacturers. According to Charleston County Aviation Authority in 2018, freight movement increased by 36 percent in a 5-year period. However, similar to MIA, its key position in the hurricane’s common path has resulted in intermittent closures for 3-4 days during the passage of Florence and Dorian. The airport is currently operating at just 5 percent capacity due to the COVID-19 outbreak.

**Dallas/Fort Worth International Airport (DFW)** is the largest hub for American Airlines and has been recognized as a major air cargo hub in 2018. According to DFW, it handles 65 percent of domestic cargo and 35 percent for international freight to markets in the Americas, Asia, Middle East, and Europe. Its air cargo hub is important to Northern Texas, accounting for USD 20 billion (EUR 18 billion) to the region yearly with its strong transit freight connections to Latin America and Asia for e-commerce. Nevertheless, DFW is also vulnerable to hurricanes. In 2019, Hurricane Dorian affected flight routes between DFW Airport and Orlando and to the Bahamas.

**Luis Muñoz Marin International Airport (SJU)** is Puerto Rico’s main airport and serves as an important hub for pharmaceutical and medicine exports to the U.S., particularly to Miami. In the wake of COVID-19 cases in Puerto Rico, local authorities have banned passenger flights from COVID-19 hotspots in the U.S. including New York, Florida, New Jersey, Pennsylvania, Connecticut, and Illinois while the island-wide lockdown is in effect until May 25. Similar to the U.S. airports that are on the common paths of hurricanes, SJU occasionally faces intermittent disruptions. In 2017, Hurricane Maria’s devastating impact on the island partially damaged the airport’s infrastructure and caused a temporary closure.
RECOMMENDATIONS
While no location can be completely impervious to the impact of a passing storm, the recommendations listed below can help organizations prepare for the upcoming tropical storm season, especially in light of the ongoing COVID-19 pandemic.

- **Map and visualize key supply chain entities:** Companies should map and visualize key assets in their supply chain network to gain a comprehensive picture of where they operate, source from, and which transportation hubs are frequently used. Having a good understanding of the network will help set the foundation to further analyze the potential impact of an upcoming storm on the business, including risks to individual shipments, products, and revenue.

- **Plan inventory ahead:** Monitor current inventory levels and plan for additional inventory within the network to ensure that production schedules can be met in case critical sourcing locations are disrupted by a tropical storm. In light of COVID-19 and in anticipation of different geographical regions experiencing additional waves of infection and the possibility of subsequent lockdown measures being imposed to contain them, organizations are advised to consider planning inventory in diverse locations to minimize the risk of not being able to quickly access or ship the inventory when needed.

- **Know what to prioritize:** In times of a crisis, companies are required to make fast decisions to continue maintaining service levels and delivering to their end customers. Understanding which products have significant revenue impacts and prioritizing locations that are used to either source components/materials for or manufacture those products will help organizations focus their business continuity efforts during a crisis. Companies can also liaise with logistic providers to prioritize and expedite time-sensitive shipments that may be affected by a tropical storm’s passage.

- **Establish detailed contingency plans:** As tropical storms occur annually, companies should proactively develop hurricane preparedness plans prior to the storm’s peak season. This can involve establishing alternative communication mechanisms in the event that power lines and phone connectivity are unavailable, prepositioning emergency fuel in key locations to ensure backup generators are up and running in the aftermath of a storm, and having a protocol defined with employees on what to do in case a storm is about to make landfall. Scenario planning and establishing protocols can save costs while protecting the organization’s reputation.

- **Keep abreast of storm alerts during peak season:** Organizations need to be well-informed of brewing storms that may disrupt production lines and shipment delivery, particularly during the respective peak seasons. While the storm’s trajectory and wind speed may change at any given time, it is important to be aware of the storm forecasts and any preemptive measures being adopted by local authorities, like port closures, shelter-in-place orders, or grounding of flights. Customers can also monitor developments on Resilience360.

- **Maintain effective communication with key partners:** It is important for companies to have well-established relationships and communication channels with material suppliers and freight forwarders to work collaboratively in order to mitigate the impact from a storm. During a crisis, coordination and communication are necessary to find an effective solution with the aim to keep cargo moving. Suitable risk monitoring tools can also help organizations have on-the-ground intelligence on capacity availability and constraints, closure of affected cargo transportation hubs, and the latest information on service cancellations to aid in the discussion with key partners on the best course of action to take.
APPENDIX
## Appendix A: Impact of severe tropical storms between 2017 and 2019

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Tropical Storm</th>
<th>Countries Affected</th>
<th>Total Cost of Damage</th>
<th>Impact on Supply Chains</th>
</tr>
</thead>
</table>
| August 2017    | Cat 4 Hurricane Harvey | United States, Caribbean Islands | USD 125 billion (EUR 115 billion) | - Freight rail traffic along the Gulf Coast from Brownsville, Texas to Lake Charles, Louisiana suspended as well as services between Houston and Laredo and embargoed cross-border traffic via Laredo and Brownsville/Matamoros  
- Major refineries along the Houston Ship Channel and the Colonial Pipeline faced operational problems, diesel supplies significantly reduced in Houston, Dallas and San Antonio |
| August 2017    | Cat 5 Hurricane Irma       | United States, Caribbean Islands | USD 77.16 billion (EUR 71 billion) | - Freight transportation via rail was largely suspended across Florida and in some parts in Georgia as well as South and North Carolina States  
- Automotive, aerospace, life sciences and healthcare, electronics, semiconductor, textile, paper, chemical, fuel  
- 4,110 flights cancelled at Florida airports and 1,300 flights cancelled in Atlanta  
- > 6.5 million power outages across Florida and one million power customers were offline in Georgia and the Carolinas |
| September 2017 | Cat 5 Hurricane Maria       | Dominican Republic, Puerto Rico | USD 91.61 billion (EUR 82 billion) | - 1.5 million homes and businesses lost electricity across Puerto Rico  
- About 50 pharmaceutical plants halted production |
| August 2018    | Cat 4 Hurricane Florence    | United States           | USD 24.23 billion (EUR 21.8 billion) | - Approx. 2,200 flights cancelled |
| September 2018 | Cat 5 Typhoon Mangkhut       | Philippines, Malaysia, Taiwan, China, Vietnam | USD 3.77 billion (EUR 3.59 billion) | - 89 flights were cancelled at HKG, 2,000 flights rescheduled |
| October 2018   | Cat 5 Hurricane Michael      | Cuba, United States     | USD 25.1 billion (EUR 22 billion) | - Cuba lost 70 percent of its power  
- 1.2 million homes and businesses were without power in several US east coast and southern states |
| August 2019    | Cat 4 Typhoon Faxai          | Japan                   | USD 8.12 billion (EUR 7.31 billion) | - Highways and railways in the Tokyo region close  
- Power outage across 730,000 customers  
- Production halted at refineries, plastic, rubber, electronic factories in Chiba prefecture |
| August 2019    | Cat 4 Typhoon Lekima         | China                   | USD 9.28 billion (EUR 8.3 billion) | - 3,033 flights cancelled  
- Petrochemical, aluminum, and steel industries in Shandong were impacted |

*33 2020 Tropical Storm Season Outlook*
<table>
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<th>Countries Affected</th>
<th>Total Cost of Damage</th>
<th>Impact on Supply Chains</th>
</tr>
</thead>
</table>
| August 2019| Cat 3 Typhoon Krosa     | Japan                                                  | USD 20.4 million (EUR 18 million)  | 4  
|            |                         |                                                        |                                    | No record 
|            |                         |                                                        |                                    | • Around 800 flights and train services have been cancelled in Hiroshima prefecture |
| August 2019| Cat 5 Hurricane Dorian  | Bahamas, Puerto Rico, United States, Greenland, Canada | USD 4.68 billion (EUR 4.21 billion) | 7  
|            |                         |                                                        |                                    | 14  
|            |                         |                                                        |                                    | • 13,000 buildings damaged in the Bahamas 
|            |                         |                                                        |                                    | • Over 250,000 homes and businesses in coastal areas of South Carolina were without power |
| September 2019| Cat 2 Typhoon Mitag     | China, South Korea, Japan, Taiwan, Philippines         | USD 816 million (EUR 755 million)  | 4  
|            |                         |                                                        |                                    | No record 
|            |                         |                                                        |                                    | • Power outages 80,000 across customers in Taiwan 
|            |                         |                                                        |                                    | • 625 flights at airports in Beijing, Shanghai, Guangzhou, Shenzhen and Chengdu |
| November, 2019| Cat 2 Cyclone Bulbul   | Thailand, Bangladesh, Myanmar, India                   | USD 3.38 billion (EUR 3.04 billion) | 6  
|            |                         |                                                        |                                    | No record 
|            |                         |                                                        |                                    | • Flights in and out of India's Kolkata airport were suspended for 12 hours |
Resilience360 enables companies to visualize, track, and mitigate risks in their supply chain. The Resilience360 suite of solutions enables intuitive visualization of supplier networks, tracks shipments across different modes and lanes, and permits near real-time monitoring of incidents capable of disrupting supply chains. Resilience360 provides companies a first mover advantage in detecting and verifying risks using both Artificial Intelligence and a human network of DHL employees in 220 countries and territories. Customers trust Resilience360 to ensure business continuity, identify critical hotspots to mitigate risks, and turn potential disruptions into a competitive advantage.

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