# WINDSTORMS

## INTRODUCTION

A variety of windstorms occur throughout the world on a frequent basis. Although most winds are related to exchanges of energy (heat) between different air masses, there are a number of weather mechanisms that are involved in wind generation. These depend on latitude, altitude, topography and other factors. The different mechanisms produce windstorms with various characteristics. Some affect wide geographical areas, while others are local in nature. Some storms produce cooling effects, whereas others rapidly increase the ambient temperatures in affected areas. Tropical cyclones born over the oceans, tornadoes in the mid-west and the Santa Ana winds of Southern California are examples of widely different windstorms. The following is a short description of some of the more prevalent wind phenomena.

A glossary of terms associated with windstorms is provided in PRC.15.1.1.A. The Beaufort Wind Scale, the Saffir/Simpson Hurricane Scale, the Australian Bureau of Meteorology Cyclone Severity Scale and the Fugita Tornado Scale are also provided in PRC.15.1.1.A.

## Types Of Windstorms

### Local Windstorms

A variety of wind conditions are brought about by local factors, some of which can generate relatively high wind conditions. While they do not have the extreme high winds of tropical cyclones and tornadoes, they can cause considerable property damage. Many of these local conditions tend to be seasonal.

Cold weather storms along the East coast are known as Nor'easters or Northeasters. While their winds are usually less than hurricane velocity, they may create as much or more damage. While the hurricane moves fairly rapidly, the slow-moving Nor'easter may bring winds of 50 mph – 60 mph (80 km/h – 97 km/h) for hours or even days.

Another form of very strong winds are "Downslope winds." One form of downslope wind that develops along the eastern slope of the Rocky Mountains is known as a "Chinook." These winds are not only strong, but are warm and dry. They can raise the local temperatures, causing a high rate of snowmelt, resulting in flooding. The "Santa Ana" winds in Southern California are hot and dry, establishing conditions for severe forest fires. In Alaska, "Williwaws" have gusts of up to 70 mph (113 km/h) in almost every month, along exposed portions of the southeast, south and southwest coasts.

### Thunderstorms

These are usually small but intense local storms. They may form as a series of squalls along a frontal system and can produce winds in excess of 65 mph (104 km/h). Thunderstorms can spawn tornadoes and produce heavy rains, hail and lightning, which could cause property damage.

Thunderstorms occur worldwide and tend to occur in warm weather. They tend not to seriously damage well-designed buildings or structures. They can, however, damage roofs, signs, cranes, buildings under construction and unprotected property.

Severe thunderstorms can strike anywhere in the world. On February 16 to 17, 1962, Storm Vincinette crossed England damaging 150,000 houses in Sheffield before it moved in to the North Sea. Once in the North Sea it headed toward Germany. Along with the high tide, the resulting storm surge from the storm pushed water up the Weser and Elbe Rivers, causing breaches in dikes and extensive flooding, and killing 315 people.

In southeastern England and northern France the “Great Storm of 1987” killed 24 people and uprooted 15 million trees in England alone. The highest wind gust was recorded at Pointe du Raz in Brittany, 134 mph (217 km/h). In December 1999 two storms Lothar (160 mph (250 km/h)) and Martin (123 mph (198 km/h)) passed through France, Germany, Italy, and Switzerland within two days. These two storms killed 140 people and left 3.4 million customers in France without electricity. The total costs resulting from both storms was estimated at almost $19.2 billion (over $27.8 billion in 2017).

**Tornadoes**

The tornado is nature’s most violent storm. It can cause severe loss over a limited area. The intensity and localization of a tornado is evidenced by the swath of destruction along a path through “undamaged” areas. A “strong” tornado may be 200 yds (180 m) wide, have vortex winds on the order of 200 mph (322 km/h), a forward travel speed of 30 mph (48 km/h) and may maintain touchdown along a path 2 mi (3 km) long. Tornadoes have been indexed on the Fujita Tornado Wind Intensity scale to F-12. The most common occurrence is in the F-0 to F-5 range. Damage may be near total destruction to everything above grade within the 2 mi (3 km) long and 200 yd (180 m) path. This constitutes a very narrow and short damage zone compared to the overall weather system.

In contrast, a hurricane or tropical cyclone may make landfall with winds of 135 mph (217 km/h), extend over an area of statewide dimension and have a forward travel speed of 10 mph – 15 mph (16 km/h – 24 km/h). Widespread damage may range from moderate to severe throughout the hurricane storm area, resulting in a total storm damage loss significantly higher than from the more severe, but narrow tornado. These features account for the lower total storm damage potential of a tornado when compared to a hurricane. The damage incurred at an individual risk or in the locale of touchdown will, however, be considerably more severe.

Tornadoes are associated with severe weather fronts and, in particular, thunderstorms. All severe thunderstorms are potential tornado-producers. Although prevalent with thunderstorms, lightning, heavy rain and hail do not necessarily accompany the touchdown area of all tornadoes.

Tornadoes are common in Argentina, Australia, Bangladesh, Brazil, China, England, Japan, New Zealand, South Africa, United States, northern Europe, western Asia, and Canadian Plains. The United Kingdom has the highest occurrence rate, 0.14 per 1000 $km^2$ per year, and an average of 34 per year. According to the National Ocean and Atmospheric Administration from 1991 to 2010 there were on average 1253 tornadoes in the United States per year. Texas had the most at 155 per year followed by Kansas at 96, Florida at 66, Oklahoma at 62 and Nebraska at 57 per year. Europe has about 300 tornadoes per year and Australia and New Zealand have about 20 tornadoes per year.

The deadliest (747 fatalities) and longest (151 to 235 mi (243 to 378 km)) Tornado occurred on March 18, 1925 in the US. The track crossed from southeastern Missouri, through southern Illinois, then into southwestern Indiana. On May 21, 1950, a tornado which touched-down at Little London, Buckinghamshire and tracked 66½ mi (107.1 km) to Coveney, Cambridgeshire, England. On June 9, 1984 22 tornadoes, at least one F5, one F4 and one F3 occurred in western Russia killing over 400 people and damaged 36 cities and villages. On April 26, 1989, a tornado approximately 1 mi (1.5 km) wide and about 50 mi (80 km) long was the world's deadliest tornado, striking the Manikganj District of Bangladesh, killing an estimated 1,300 people and injuring 12,000.

In the United States, tornadoes most often occur in the central and gulf coast states during the Spring (April, May and June). They usually travel in a northeasterly direction. Figure 1 illustrates the distribution of tornadoes in the U.S. and shows where the major tornado threats occur. In Europe, tornadoes most often occur between June and August.

New records were established in 1990 for the number of “violent” tornadoes. A violent tornado is classified F-4 or F-5. All states except Maine, Vermont, New Hampshire Oregon, Hawaii and Alaska have experienced tornadoes since 1990.

Large severe weather systems may give rise to an “outbreak” of multiple tornadoes over a wide area within a short period of time. The largest known “super outbreak” occurred April 3-4, 1974. One hundred forty-eight tornadoes were spawned over 13 states as shown in Figure 2. Another outbreak occurred on November 23, 1981, where 105 tornadoes touched down in Wales and England, spawned by a cold front passing through the country.

A severe outbreak occurred June 2, 1990 in the U.S. northern plains. Although not a record breaker, 64 tornadoes crossed 8 states from Minnesota east to Ohio. Seven of these reached F-4 intensity.

While it is possible to provide some degree of “emergency” protection for buildings exposed to hurricane winds, it is not feasible to try to plan emergency measures for buildings against approaching tornadoes.

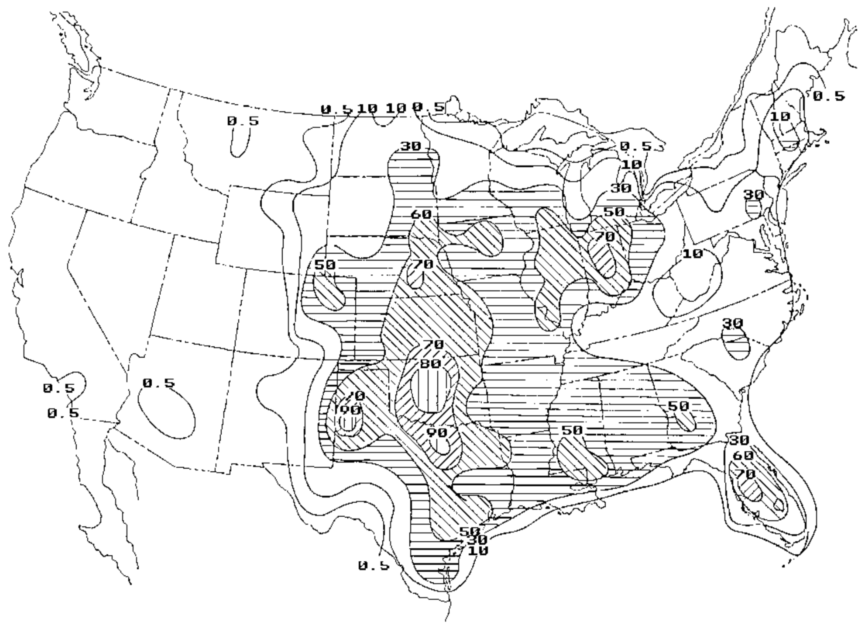

**Figure 1**. Average Annual Tornado Incidence Per 10,000 mi$^2$ (25,900 km$^2$), 1953-1980.
Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration
NYAA/PA 82001, January 1982.

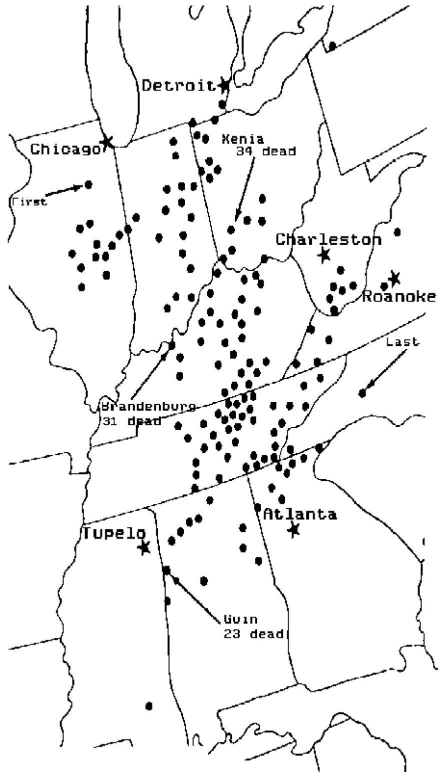


**Figure 2**. Tornado Outbreak, April 1974.

Current study suggests that buildings do not “explode” because of pressure differences as the tornado passes. The illusion that a tornado “skipped over” one building in its path appears equally accountable to construction differences. The same construction techniques applied to increase earthquake and hurricane resistance will work as well against tornado forces. Improved roof-to-wall construction connections can mitigate damage.

**Cyclones**

Tropical cyclones are severe storms that bring together three of the worst elements of weather: high winds, torrential rain and ocean storm surge. They also spawn tornadoes. These in turn cause a small zone of extremely high wind speeds within the cyclone. Some areas, such as the northeast and northwest coasts of Australia, the southeast coast of Africa, the Caribbean Islands, China, India, Japan, Madagascar, northwest coast of Mexico, Philippines, Taiwan, the east coast and gulf coast of the United States, and Vietnam, are susceptible to cyclone landfall.

There are three type of cyclone windstorm depending on the wind speed. When a storm first develops, it is called a tropical depression. Once the wind speeds reach 39 mph (63 km/h) they are then called tropical storm. When the wind speeds reach 74 mph (119 km/h) they are then called tropical cyclones. In rare instances tropical cyclone wind speeds have exceeded 200 mph (322 km/h).

Tropical cyclones are known as hurricanes in the north Atlantic Ocean, eastern Pacific Ocean and around Hawaii; cyclones in the southern Indian Ocean and the seas around Australia; and typhoons in the northwest Pacific Ocean. Severe tropical cyclones occur in seven major ocean basins of the world. They usually originate between July and October in the tropical areas and gradually dissipate as they travel toward the poles. In the past, detailed information on tropical cyclone size and movement was difficult to obtain so that often there was not sufficient time to prepare for the storm. However, satellite data is improving the capabilities of storm forecasting all over the world.

A tropical cyclone can do extensive damage over a wide geographical area. Wind speeds are high, torrential rain becomes wind driven and storm surge can cause coastal flooding. While mitigation efforts may not be totally effective against tornadoes spawned by the storm, damage control against the perils of wind, rain and flood from the tropical cyclone are effective.

While the maximum wind speeds of tropical cyclone are experienced near the storm centers, gale force winds in excess of 50 mph (81 km/h) may extend out 200 miles (322 km) from the center. Tropical cyclone approaching a coastline from the ocean can cause storm surges or tidal flooding by wind-driven water and low atmospheric pressures. Depending on elevations and topography, these surges can cause coastal flooding inland. As tropical cyclone progress overland, they frequently create heavy rainfall over wide areas. These rains can result in extensive inland flooding from rising rivers and streams.

When winds exceed 155 mph (250 km/h), their force can be expected to produce substantial damage to most buildings and structures in its path. Tropical cyclone can spawn tornadoes that cause damage to anything in their paths.

Since tropical cyclone are fueled by heat from the oceans, they are dependent on them for their energy. If the tropical cyclone moves inland, it will gradually dissipate due to the lack of heat input and frictional losses as it moves over the land mass. In some cases, storms move inland and then recurve over the ocean where they regain energy and intensity. The energy in these storms is so great that when they move inland over the eastern U.S., the strong winds and heavy rains sometimes continue until the storm reaches Canada.

Tropical cyclones continue to cause extensive damage because the general populace often does not appreciate the force and potential destruction of such storms. People tend to react slowly and inadequately to forecast warnings. Even where conservative building codes exist, people are prone to accept lesser design criteria for buildings and structures.

The fastest wind speed from a tropical cyclone gust was recorded on April 10, 1996 when Tropical Cyclone Olivia passed by Barrow Island, Australia, and the wind gust reached 254 mph (408 km/h).

In November 2013 Typhoon Haiyan made landfall on the Philippines with wind of 195 mph (314 km/h). The typhoon caused a 15 to 19 ft (4.5 to 5.8 m) storm surge. The typhoon and storm surge left 7,300 people either dead or missing.

## POSITION

### Management Programs

While proper design is the primary loss control effort against windstorm, contingency planning is also important as a means of minimizing storm damage and to insure rapid recovery of operations. Good contingency planning is more likely to be found in those areas where high winds are prevalent. In those areas where strong winds are not a regularly recurring problem, advance planning may be less satisfactory. In areas of widely varying seasonal weather and different types of storm threats, contingency planning should be coordinated with the planning for blizzards, floods or other natural phenomena. Effective planning should eliminate redundancy in plans and equipment. For some events, such as tornadoes, a slightly different emphasis may be required in the contingency planning activity.

As with any contingency plan, drills should be held to determine which procedures work and which need improvement. For windstorm plans, an annual drill provides the opportunity to update personnel assignments and inventory emergency equipment and supplies.

#### Local Storms

Plan for local windstorms the same as for tropical cyclone. While these storms normally do not produce the maximum sustained high winds of a tropical cyclone, the wind speeds could reach tropical cyclone strength and cause the same damage.

### Tornadoes

Make most preparations for property protection ahead of time. Once a tornado is sighted, there may only be time enough to secure hazardous processes and for personnel to seek shelter. Make provisions to monitor all “tornado watch” and “tornado warning” alerts. Locate high value equipment in the most substantial building available so that it receives maximum protection from the building structure.

Lower booms, buckets and similar appendages for cranes and other equipment to the ground. In operations where uninterrupted power is important, where dangerous materials can be released or where damage can cause explosion or other catastrophe, provide for operational shutdown when a tornado warning is received. Clearly define responsibility for such decisions so that prompt and effective action is assured.

Do not store loose materials in the open during the tornado season. Securely anchor temporary equipment, such as trailer offices, to the ground in a protected area where possible. Even though such light structures will not survive a direct tornado strike, secure them in place to avoid the damage that they can inflict upon other property.

### Tropical Cyclone

Complete a contingency plan for tropical cyclone before the tropical cyclone season occurs. Review and supplement the plan at the beginning of each season. Perform the actual preparation as the storm approaches. Include in the plan:

- What materials or equipment will be needed;
- What processes must be shut down;
- The time intervals required for these preparations.

If the evacuation of the facility or the residential areas which house the plant workers is likely to occur, allow sufficient time in the plans to protect the plant **and** release the workers in time to evacuate. Assign someone responsible to decide:

- When to begin storm preparations;
- When to shut down operations;
- When the emergency organization should be activated.

Assign personnel to check all doors, windows and openings and to install storm shutters or protective panels. Inspect roofs for loose covering and accessories. Move all loose outdoor equipment inside or secure it in place. Anchor large equipment, such as cranes and draglines, in accordance with predetermined plans. It may not be possible to prepare anchorages and acquire chain and other equipment at the last moment. Lower to the ground booms, buckets and similar appendages to cranes and other heavy machinery to achieve as low a center of gravity as possible.

Provide emergency supplies and equipment ahead of time as part of the contingency plan. As a storm approaches, many common items will disappear from store shelves and become generally unavailable as others also begin to make their individual storm preparations.

Normal fire protection may be impaired or nonexistent as a result of the storm and water supplies and surveillance systems may not function. Provide portable extinguishers and additional fire patrols if this occurs. Prearrange emergency communications within the facility and with outside civil defense groups.

Since storm conditions and the aftermath can last for days, temporary living quarters for the emergency staff might be required. Emergency food and water supplies and bedding will be needed. Emergency electrical power sources and heat will also be needed to sustain an emergency crew. Provide emergency equipment and repair supplies in a separate storage area. Periodically inventory and renew equipment and supplies as necessary to insure readiness. Such material might include lumber, canvas, piping, plastic sheeting, roofing paper, generators, pumps, saws, sand bags, ladders, rope, wire and miscellaneous hand tools. Properly store sufficient fuel supplies for engine driven equipment. Include in the plan provisions for post storm clean up and salvage operations. In particular, make inspections to detect broken wiring, leaking tanks, structural damages and other hazardous conditions. Also include in the plan names and phone contacts for contractors with capabilities needed for clean up and repair services.

AXA XL Risk Consulting's *OVERVIEW* contains information and sample check lists for floods and hurricanes. A sample tracking chart is also included to assist in monitoring a storm approach.

### General

Design all buildings and structures in accordance with local building design standards that cover wind loading[1] or an equivalent construction standard and PRC.2.0.1.1. When using any of the design standards, use the highest Risk Category, Working Life, or equivalent when designing essential buildings or structures.

Pay particular attention to the design of roof anchorage, anchorage of roof mounted structures, roof cover mechanical fastenings and flashing securement. Install glazing materials that have been tested to withstand impact from debris. Also provide windows and doors with secure latches and tight closures. Avoid installing large glass areas. Large vehicle loading doors are typically loose fitting; therefore, provide suitable weather tightness and latch down devices, which can be used to prepare for storm approach.

## DISCUSSION

Tropical storms are large weather systems, which begin as low pressure regions over warm open ocean. These are called depressions. When the system becomes convective and winds begin to swirl around a central region with low wind speeds the system becomes a tropical storm. At a wind speed of 40 mph (64 km/h) the storm reaches gale force.

Tropical cyclones are not charted around the South American continent in either the south Atlantic Ocean or the eastern Pacific Ocean off South America.

Tropical cyclones are 100 mi (160 km) or more in diameter with very high wind speeds within 20 or 30 mi (32 to 48 km) of the center. Winds swirl around the center and inward toward the central core or "eye" which consists of relatively calm, warm and often clear air. The diameter of the eye usually ranges between 12 and 30 mi (19 and 48 km). The more intense the storm the smaller the eye.

Clouds stack in vertical bands around the initial core creating a wall at the outer edge of the eye. This eyewall is the zone of strongest winds. Rain bands generate in this area also. Destructive hurricane-force winds spread outward from the eye to 60 mi (97 km) or more with gale-force winds (above 40 mph [64 km/h]) extending outward an additional 100 mi (160 km) making a storm 320 mi (394 km) in diameter. Prevailing high altitude wind currents steer the entire system progressively along a path.

Tropical cyclones are severe storms that bring together three of the worst elements of weather: high winds, torrential rain and ocean storm surge. They also spawn tornadoes. These in turn cause a small zone of extremely high wind speeds within the cyclone. Some areas, such as the east coast and gulf coast of the United States and the east and west coasts of Australia, are susceptible to cyclone landfall. The regions in which tropical cyclones form and the historical paths they take are known (see Figure 3). Historical data also identifies the seasonal time of year storms most frequently form in the various regions. Storm seasons are June to November for north Atlantic hurricanes and broadly, November - December to April - May for southern ocean cyclones and western Pacific typhoons.

Tropical storms originate in the tropics. As a general guidance, sea temperature limits the area of genesis. Sea temperature lower than 80.6°F (27°C) is not conducive to tropical cyclone development. While there may be a good deal of atmospheric disturbance near the equator, tropical cyclones do not take shape there. They originate within the zone 5 -15 degrees latitude. The storms forward movement is westerly both in the northern and southern hemispheres.

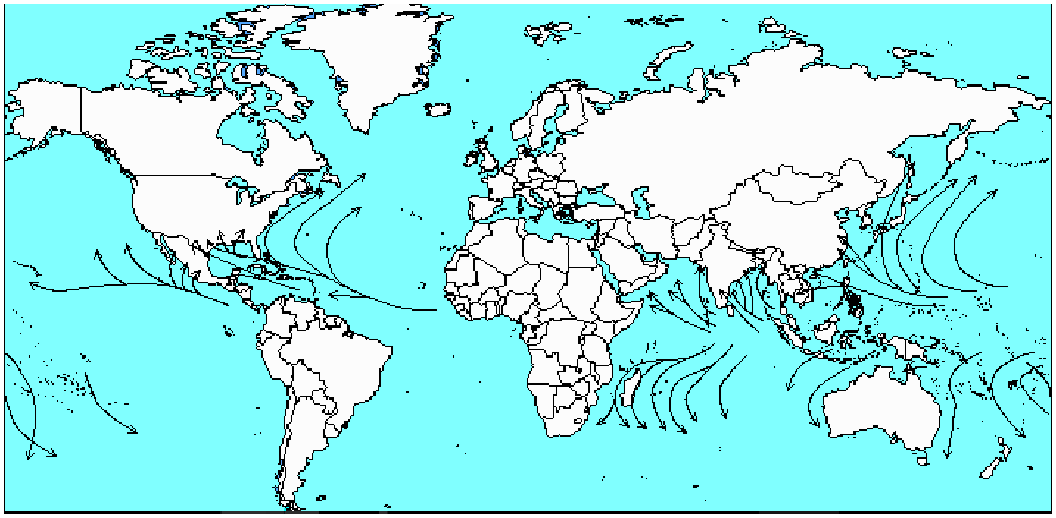

**Figure 3**. Tropical Cyclone Tracks.

Due to the Coriolis Effect, storms in the northern hemisphere (north Atlantic, north Pacific and north Indian Oceans) usually turn north while revolving counter-clockwise around the eye. Storms in the southern oceans track south while revolving clockwise around the eye. The satellite views in Figure 4 and Figure 5 show the spin direction. Since the forward travel speed (10 mph – 30 mph [16 km/h – 48 km/h]) is additive to rotational speed, the most intense area of the storm occurs in the forward right quadrant of northern hemisphere storms and in the forward left quadrant of southern hemisphere storms.

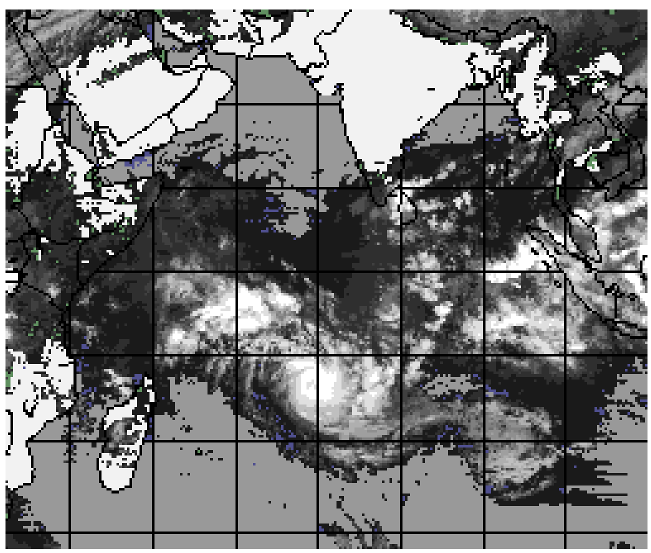

**Figure 4**. Clockwise Rotation, Southern Oceans.

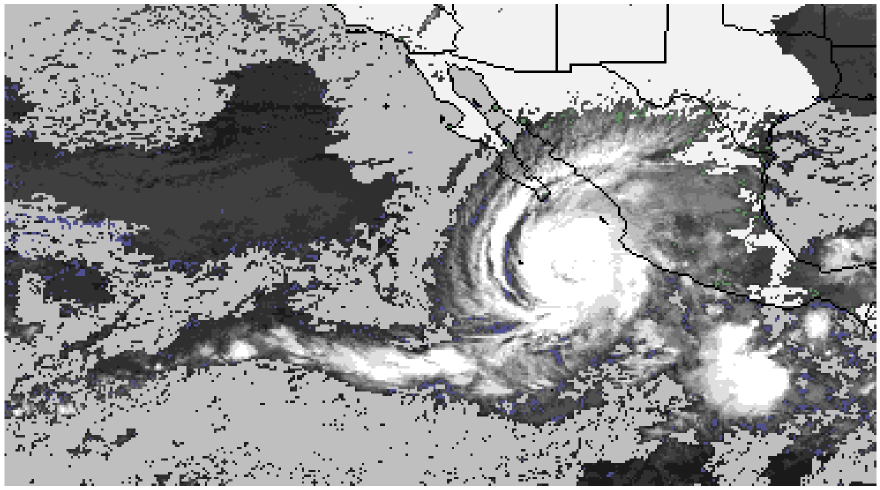

**Figure 5**. Counter Clockwise Rotation, Northern Hemisphere.

Protection against damage from tropical cyclones begins with a structural design to withstand the pressure of cyclone wind speeds, quality workmanship in construction and good maintenance. Code designs incorporate resistance to the strongest winds normally anticipated within a region. Where cyclonic disturbance may be expected, such as coastal zones, a minimum design wind speed of 100 mph (160 km/h) is commonly required and 110 mph – 125 mph (177 km/h – 201 km/h) is deemed necessary in some areas. Wind design affects many structural features. The roof of a building is the most severely exposed building element.

While proper design efforts are the primary loss control effort against windstorm, contingency planning is also important to minimize storm damage and to insure rapid recovery operations. Good contingency planning is more likely to be found in those areas where high winds are prevalent. In those areas where strong winds are not a regularly recurring problem, advance planning may be less satisfactory. In areas of widely varying seasonal weather and different types of storm threats, coordinate contingency planning with the planning for blizzards, floods or other natural phenomena. Eliminate redundancy in plans and equipment through effective planning. For tornadoes, a slightly different emphasis may be required in the contingency planning activity.

As with any contingency plan, holding drills helps determine which procedures work and which need improvement. For windstorm plans, an annual drill provides the opportunity to update personnel assignments and inventory emergency equipment and supplies.

The construction and location of a facility influences the exposure of buildings to damage. While construction design, quality of workmanship and maintenance determine a building's ultimate resistance to wind damage, the wind resistance qualities of the ground surface area nearby may reduce the effective windspeed to some degree. Open water and flat ground topography, stands of trees and groups of structures create barriers, which offer frictional resistance and slow the effective wind speeds.

Wind pressures act in a vertical plane on a building causing uplift and in a horizontal plane causing sliding or overturning. Uplift negative pressures allow the roof to lift off the walls. The roof structure needs to be securely anchored to the walls and the walls to the foundation. Loose covering, flashing or rooftop structures can lift and separate from the roof framing if they are not adequately secured and maintained.

The horizontal wind pressures push walls, windows and doors inward from the outside or outward from the inside if the building is opened and the wind pressurizes the building. If a building component (window or door) is structurally sound and adequately connected, it will transmit the force produced to the wall and foundation. If the wall is adequately secured to the foundation, the building wall successfully resists the wind and no damage results. However, if one component fails, that failure may lead to partial or total collapse of the structure.

It is important the building enclosure (doors, windows, walls and roof) be structurally sound, well maintained and unpenetrated. Inadvertent opening of the building enclosure, known as a “weather envelope,” may internally pressurize the building interior and lead to structural failure during the storm.

Loose materials on the roof or on the ground or yard storage can quickly become flying missiles capable of penetrating the building enclosure.

The very low atmospheric pressure associated with a tropical cyclone induces a rise in the sea level in the central area of the storm. The high ocean water level associated with tropical storms is due to this cyclonic storm surge. This is a dome of water or local rise of sea that results as the central low pressure field of the eye of the storm passes. Over open ocean, the water is elevated one foot or more due to the pressure differential. At the same time, strong winds generate turbulent seas and high waves. Storm produced waves may reach 50 ft (15 m) or more in height. As the storm approaches coastal waters, the surge level is in addition to the astronomical tide of the region. If storm landfall coincides with local high tide, coastal flooding is to be expected. If storm landfall occurs at low tide and moves landward before the incoming tide arrives, coastal flooding may not be catastrophic. The storm surge may be 4 – 20 ft (1.3 m – 6 m) high above astronomical high tide and affect an area of 35 miles – 50 miles (56 km – 80 km) diameter. The combination of high water and wind driven high wave action accompanying tropical cyclones, causes severe damage to coastlines.

As the storm moves inland the large amounts of moisture result in torrential rains. The tropical cyclone can drench the areas it crosses with 12 in. (30 cm) or more of rain. The rains can last long after the strong winds dissipate. Consequent river flooding from the inland torrential rains may also impose disastrous flooding.

The combination of wind and rain, floodwater undermining foundations and wave action pounding structures along the coast can result in extensive damage. Wind driven rain can produce substantial structural and interior damage to building and content if the building envelope is damaged.

The National Weather Service of the National Oceanographic and Atmospheric Administration (NOAA), assisted by other government agencies, tracks hurricanes and issues information and warnings to the public when the U.S. coast is threatened. They will issue the “Hurricane Watch” and “Hurricane Warning.”

The National Weather Service also operates an alert system that attempts to provide advance warning to the general populace during the tornado season. The system operates in two phases; “tornado watch” and “tornado warning.”

## Wind scales

Tropical storms are classified by wind speed. Following is a brief comment concerning wind scales. Each of the following scales identifies wind speed ranges and effects expected. Full scales are included - PRC.15.1.1.A.

- The **Beaufort wind scale** developed by early Atlantic Ocean Mariners identifies wind speeds up to force 12 (75 mph [120 km/h]). Beaufort force 12 and higher winds and torrential rains combine with ocean storm surge which can be 4 ft (1.3 m) or more along the coast to cause wind and water damage and coastal flooding. Inland, the flooding takes the form of river and stream flood and excessive surface runoff.
- The tornado wind intensity scale, known as The Fugita scale, begins at F-O, 40 mph – 72 mph (64 km/h – 116 km/h).
- The Saffir/Simpson Hurricane scale, developed at the U.S. National Hurricane Center, begins at category 1, winds of 74 mph – 95 mph (119 km/h – 153 km/h). Hurricanes rated in the 3, 4 and 5 categories of intensity on this scale are major storms with extensive damage potential. Cyclones located in the Indian Ocean and the areas around Australia or typhoons located in the Western Pacific Ocean are also rated in the same categories for severity.

- The Australian Bureau of Meteorology, Emergency Management warning system marks category 1 severity at 125 km/h (78 mph) strongest gust. (Gust wind is measured for 2 s – 5 s; sustained wind is measured for 1 min.)

A further storm scale is being developed for the Atlantic Coastal Storm (Nor'easter). This index of storms, known as the **Dolan - Davis Nor'easter Classification scale**, is based upon wave height and duration.

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KGG – KBC 2005 -*Korean Government Guidelines of Korean Building Code*, Korea.

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# WINDSTORM GLOSSARY

**Coriolis Force** - The apparent force caused by the earth's rotation that deflects a moving body to the right in the northern hemisphere and to the left in the southern hemisphere.

**Cyclone Season** - Period of more frequent tropical cyclone activity - Southern Hemisphere (November - April).

**Eye** - The warm and calm core of cyclone. A relatively calm area rising from the surface to the top of the storm and surrounded by walls of massive cumulonimbus clouds. The boundary of the eye marks where the force of inward spiraling air balances the outward centrifugal force of rotation.

**Eye Wall** - Vertical bands of clouds surrounding the eye. This area corresponds to the maximum inward penetration of inward spiraling air. This is the area of the cyclone where the winds are the strongest.

**Flood**

- Flood - A temporary condition of inundation from (1) inland or tidal waters or (2) unusual accumulation or runoff of surface waters.
- Flood Watch - Flooding is possible in the area.
- Flood Warning - Flooding is imminent.

**Gust Wind Speed** - The maximum wind speed average over a period of from 2 s – 5 s. Generally the gust speed is 20% – 30% higher than a corresponding sustained speed.

**Hurricane Season** - Period of more frequent tropical cyclone activity in the Atlantic Ocean, Caribbean Sea and Gulf of Mexico (June - November).

**Hurricane Warning** - An advisement usually issued 24 hours prior to the storm, indicates hurricane conditions are expected. If the hurricane path changes, the warning may be issued 10 to 18 hours or less before the storm makes landfall.

**Hurricane Watch** - An advisement indicating hurricane conditions are a real possibility, usually within 24 to 36 hours, but it does not mean they will happen. The watch covers a definite area and time period.

**Land Fall** - The location where the eye of the cyclone crosses the coast line.

**Storm Surge -** The rise of sea level accompanying a tropical cyclone. A dome of water results as the central low barometric pressure field at the eye of the storm passes. Wind also enhances wave action and a local “buildup” of water volume. At the storm approaches land the storm surge can cause coastal flooding.

**Sustained Wind Speed** - The wind speed averaged over a period of one minute.

**Tornado Warning** - An advisement when tornadoes are occurring. The area of occurrence will be identified.

**Tornado Watch** - An advisement when atmospheric conditions are present which are likely to spawn tornadoes.

**Tropical Cyclone** - Hurricane, Cyclone, Typhoon - By international agreement, a tropical cyclone is the general term for all cyclone circulations originating over tropical waters. Has a definite organized surface circulation. Wind speeds reach 74 mph (119 km/h) or more.

**Tropical Cyclone**

- Advisory - May be issued if the storm is expected within 36-42 hours.

- Watch - May be issued if the storm is expected within 24-36 hours.
- Warning - May be issued if the storm is expected within 24 hours or less.

**Tropical Cyclone Season** - Period of more frequent tropical cyclone activity - Bay of Bengal and Arabian Sea (April – June and September – November), East Coast of Africa (November – April).

**Tropical Depression** - An organized cyclone in which the wind speed is 33 mph (61 km/h) (33 knots) or less.

**Tropical Disturbance** - A moving corrective systems of circulating massed warm air that has maintained its identity for at least 24 hours.

**Tropical Storm** - An organized warm core cyclone in which the maximum wind speeds range between 39-73 mph (63-118 km/h) (34 to 63 knots).

**Typhoon Season** - Period of more frequent tropical cyclone activity affecting Japan, the Philippines and western Pacific (May - December).

**Severe Thunderstorms** - A storm where winds reach 58 mph (93 km/h) or more, or produce hail ¾ in. (19 mm) or more in diameter.

## Beaufort Wind Scale

| Beaufort Number | Explanatory Titles | Specifications For Use On Land | Miles Per Hour | Knots | Terms Used In Weather Bureau Forecasts |
|---|---|---|---|---|---|
| 0 | Calm | Smoke rises vertically | Less than 1 | Less than 1 | |
| 1 | Light air | Direction of wind shown by smoke drift, but not by wind vanes | 1-3 | 1-3 | Light |
| 2 | Slight breeze | Wind felt on face; leaves rustle; ordinary vane moved by wind | 4-7 | 4-6 | |
| 3 | Gentle breeze | Leaves and small twigs in constant motion; wind extends light flag | 8-12 | 7-10 | Gentle |
| 4 | Moderate breeze | Raises dust and loose paper; small branches are moved | 13-18 | 11-15 | Moderate |
| 5 | Fresh breeze | Small trees in leaf begin to sway; crested wavelets form on inland water | 19-24 | 16-21 | Fresh |
| 6 | Strong breeze | Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty | 25-31 | 22-27 | Strong |
| 7 | High wind | Whole trees in motion; inconvenience felt in walking against the wind | 32-38 | 28-33 | |
| 8 | Gale | Breaks twigs off trees; generally impedes progress | 39-46 | 34-40 | Gale |
| 9 | Strong gale | Slight structural damage occurs (chimney pots and slate removed) | 47-54 | 41-47 | |
| 10 | Whole gale | Seldom experienced inland; trees uprooted; considerable damage occurs | 55-63 | 48-55 | Whole gale |
| 11 | Storm | Very rarely experienced; accompanied by widespread damage | 64-75 | 56-63 | |
| 12 | Hurricane | | Above 75 | Above 64 | Hurricane |

**SI Units**: mph = km/h × 1.609

## Cyclone Severity Categories Adapted From Bureau Of Meteorology - Australia

| Category | Barometric Pressure (hPa.) | Strongest Gust (km/h) | Damage Potential | Typical Effects |
|---|---|---|---|---|
| 1 | 985 | less than 125 | Minor | Negligible home damage. Damage to some crops |
| 2 | 970-985 | 125 – 170 | Moderate | Significant damage to signs, trees, crops, risk of power failure |
| 3 | 945-970 | 170 – 225 | Major | Roof and structural damage power failure likely |
| 4 | 920-945 | 225 – 280 | Devastating | Significant roofing loss and structural damage. Airborne debris. Widespread power failure |
| 5 | 920 | more than 280 | Extreme | Extremely dangerous with widespread destruction |

**SI Units**: in. = hpa × 33.86; mph = km/h × 1.609

### Saffir/Simpson Hurricane Scale Adapted From U.S. National Hurricane Center

| Category | Barometric Pressure (in.) | Winds (mph) | Storm Surge (ft) | Damage Potential |
|---|---|---|---|---|
| 1 | 28.94 or more | 74 – 95 | 4.5 | Minimal (Weak) |
| 2 | 28.50 - 28.91 | 96 – 110 | 6 - 8 | Moderate |
| 3 | 27.91 - 28.47 | 111 – 130 | 9 - 12 | Strong |
| 4 | 27.17 - 27.88 | 131 – 155 | 13 - 18 | Very Strong |
| 5 | 27.16 or less | 156 or more | 18.1 or more | Catastrophic |

**SI Units**: in. = hpa × 33.86; mph = km/h × 1.609; ft = 0.305 m

### Fujita Tornado Scale

| Category | Wind Speed (mph) | Length Of Track (mi) | Width Of Track | Damage Potential | Damage Characteristics |
|---|---|---|---|---|---|
| F0 | 40-72 | 0.3-1 | 6-17 yds | Very weak | Beaufort 9-11 - Full Scale Branches off trees |
| F1 | 73-112 | 1-3 | 18-35 yds | Weak | Beaufort 12 - Hurricane Covers Roofs - Blown trees uprooted |
| F2 | 113-157 | 3-10 | 56-175 yds | Strong | Roofs Structure Torn Off |
| F3 | 158-106 | 10-31 | 176-556 yds | Severe | Roofs and walls torn down Block structures leveled |
| F4 | 207-260 | 31-100 | 0.3-0.9 mi | Devastating | Well constructed frame week foundations lifted - leveled |
| F5 | 261-318 | 100-315 | 1-3 mi | Incredible | Well constructed frame lifted off foundation |

**SI Units**: yds = m × 0.9144; mph = km/h × 1.609; mi = 1.6 km