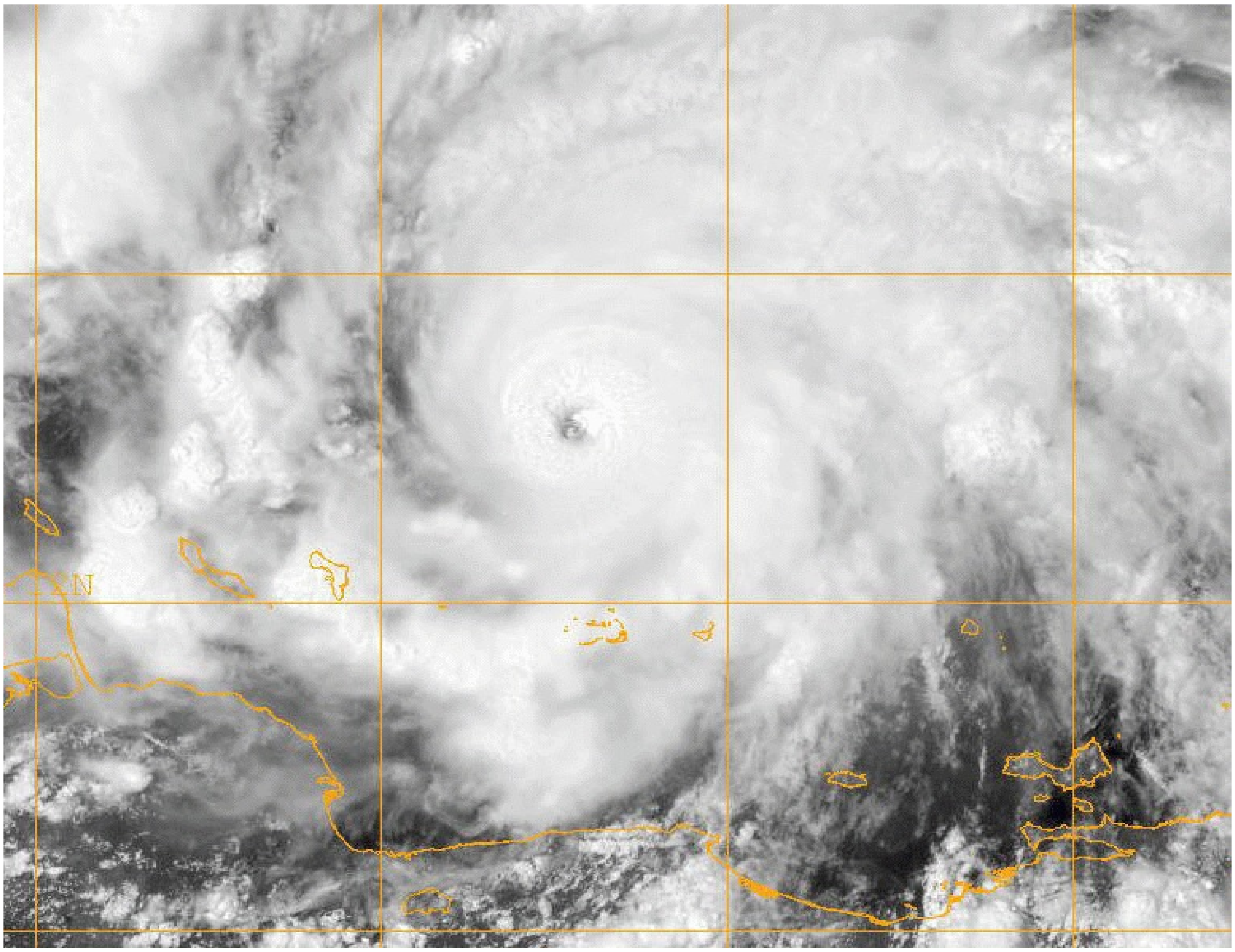
Meteorological Department Curaçao

Contributing to the protection of life and property against natural hazards



Hurricanes and Tropical Storms in the Dutch Caribbean

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Last Updated: April 2015

Introduction

The Dutch Caribbean consists of six small islands, located in two different geographical locations. The ABC Islands, Aruba, Bonaire and Curaçao near 12 degrees north, between 68 and 70 degrees west, along the north coast of Venezuela, and the SSS Islands consisting of Saba, St. Eustatius and St. Maarten near 18 degrees north, 63 degrees west in the island chain of the Lesser Antilles.
The Dutch Caribbean are an integral part of the Kingdom of the Netherlands, comprising the Netherlands in Europe and the former Netherlands Antilles in the Caribbean as partners on equal footing. The countries of Aruba, Curaçao and St. Maarten have complete autonomy as regards internal affairs, as set forth in the Constitution of these countries. The executive power of the Government is exercised by a Governor under responsibility of a Council of Ministers. The governments of Aruba, Curaçao and St. Maarten have a one-layer structure.
The islands of Bonaire, St. Eustatius and Saba are public entities (like municipalities) of the Netherlands. The executive power of the individual Island Governments of Bonaire, Saba and St. Eustatius is exercised by a Lieutenant Governor with a Council of Commissioners for each island.
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Dutch Caribbean

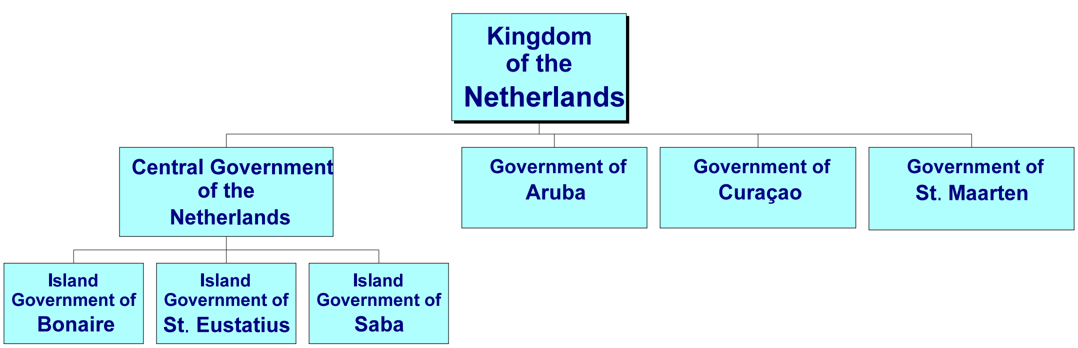
Country	Island	Location	Area	Population
Aruba	Aruba	12.5°N 70°W	193 km^2	106.800 (2013)
Netherlands	Bonaire	12.0°N 68°W	288 km^2	17.400 (2013)
Curaçao	Curaçao	12.0°N 69°W	444 km^2	153.500 (2013)
Netherlands	Saba	17.5°N 63°W	13 km^2	2.000 (2013)
Netherlands	St. Eustatius	17.5°N 63°W	21 km^2	3.900 (2013)
St. Maarten	St. Maarten	18.0°N 63°W	34 km^2	39.689 (2013)

Eastern Caribbean

Meteorological Department Curaçao.

With Aruba obtaining a separate status in the Kingdom of the Netherlands as from January 1, 1986, the provision of meteorological services in both countries was maintained in virtually the same manner as before the constitutional change when Aruba was part of the Netherlands Antilles.
On October 10, 2010, the Netherlands Antilles were dismantled and the Meteorological Service of the Netherlands Antilles and Aruba therefore ceased to exist. It was replaced in Curaçao by the Meteorological Department Curaçao (MDC). The branch in Aruba became the Departamento Meteorologico Aruba (DMA) and the one in St. Maarten was named the Meteorological Department St. Maarten. The MDC will continue to be responsible for the issuance of routine weather forecasts and also warning bulletins for Curaçao and also for the BES Islands (**B**onaire, S. **E**ustatius and **S**aba).

Government Setup



Tropical Cyclones of the North Atlantic Ocean

Over a 158-year period, 1851 through 2014, a total amount of 1483 tropical cyclones (of which 866 reached hurricane force) has been recorded over the North Atlantic Area. The formation of these storms and possible intensification into mature hurricanes takes place over warm tropical and subtropical waters. Eventual dissipation or modification, some 10 days later, typically occurs over the colder waters of the North Atlantic, or when the storms move over land and away from the sustaining marine environment. Because of the potential destructive powers of tropical cyclones, interest in them has always been great. Tropical cyclones have, in particular, always been of concern to mariners and are reasonably well documented over remote oceanic areas, at least back to the 19th century.
Although far from complete or accurate for earlier centuries, this paper even attempts to present a history of the tropical cyclones of the Dutch Caribbean as far back as the time of the voyages of discovery of Christopher Columbus.

All Storms Together

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Characteristics of Tropical Cyclones

It is beyond the scope of this paper to discuss the very details of the characteristics of tropical cyclones or the complicated atmospheric dynamics which lead to their initial formation, possible intensification, motion, and eventually, their modification or decay. Some comments are necessary however, for proper interpretation of the material presented.

Any closed circulation in the Northern Hemisphere in which the wind rotates counter-clockwise (clockwise in the Southern Hemisphere) is called a cyclone. The term "tropical cyclone" refers to such a cyclonic circulation which develops over tropical waters. Cyclones which form outside the tropics (extra-tropical cyclones) have structure, energetic and appearance (when viewed from weather satellites or radar) that are different from tropical cyclones. They are baroclinic (cold core) and derive their energy primarily from contrasts of temperature and moisture and are typically associated with cold- and warm fronts.

Tropical cyclones, with their warm core and energy derived from the latent heat of condensation of water vapor, are generally smaller in extent than extra-tropical cyclones and typically range from 200 to 1000 kilometers in diameter at maturity. Winds normally increase towards the center of tropical cyclones with sustained winds often exceeding 200 km/h near the center. Occasionally {e.g. in hurricanes Gilbert (1988), Hugo (1989), Luis (1995), Katrina, Rita and Wilma in 2005} sustained winds exceeding 300 km/h, with still higher gusts, may occur in well developed systems.

Aside from the winds, other destructive features of tropical cyclones include torrential rains over a large area, and coastal storm tides of 3 to 8 meters (10 to 25 feet) above normal in extreme cases. Indeed, flash floods with landslides and coastal inundation from the storm surge is primarily responsible for deaths and damages from these storms. A unique feature of tropical cyclones is the central "eye".

The pattern of winds does not converge to a single point, but becomes tangent to the eye wall (boundary updraft column) at a radius of about 10 to 25 kilometer or more from the geometric center.

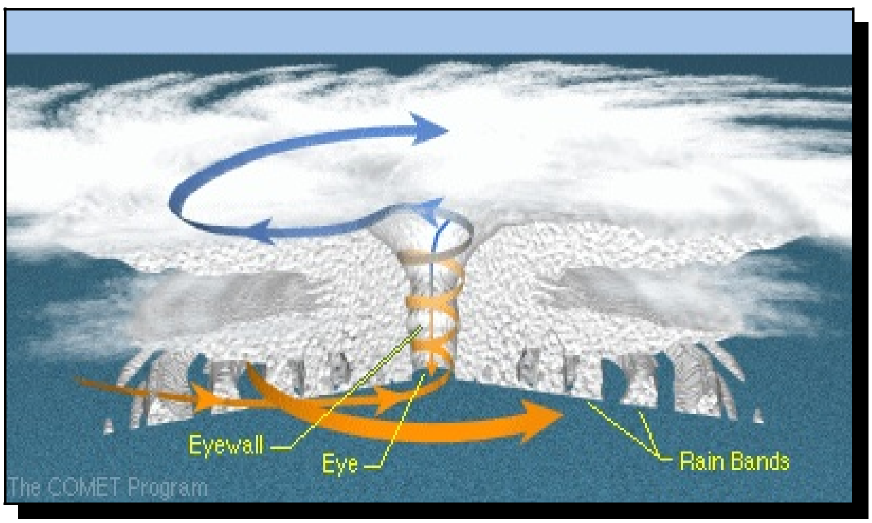
The eye is generally an area of light winds, minimum cloud cover, and minimum sea level pressure; it provides a convenient frame of reference that can be tracked with the aid of aircraft, satellites or radar. In well developed systems the eye is clearly identifiable in the center of the rotating cloud mass.

Frequency and Development of Atlantic Tropical Cyclones

In an average year, more than one hundred hurricane seedlings, tropical disturbances with hurricane potential, are observed in the Atlantic, the Gulf of Mexico and the Caribbean; but less than 25 obtain an organized cyclonic circulation and develop into a tropical depression. Of these tropical depressions, fewer than ten reach the tropical storm stage and only about six mature into hurricanes. This is not at all surprising, taken the different sources of origin and the various, known but also still unknown or not completely understood, atmospheric conditions which together determine the possibility of development. Predominantly the tropical troposphere (the lower level of the atmosphere, where most vertical air mixing and weather occur), potentially unstable as it is, maintains a delicate balance in its dynamics, even in seemingly ideal convective situations.

Satellite imagery has confirmed that some North Atlantic tropical cyclones classically develop from tropical waves which regularly move off the coast of Africa near 15 degrees north latitude. These systems are embedded in the deep easterly trade wind current and may travel several thousands of kilometers with little change in structure. But where the waves are destabilized by intense convection or by some external force - for example, a high-level wind regime that promotes greater organization of the circulation in the wave by acting as a sort of exhaust mechanism to compensate for the low level convergence - they may curl inward. The vertical circulation accelerates, and a vortex develops that sometimes reaches hurricane intensity.

Some tropical cyclones originate from the Intertropical Convergence Zone (ITCZ), the quasi-permanent equatorial region of low pressure which follows the sun. Generally, the ITCZ moves from a position near the Equator in February to its extreme limit near about twelve degrees north latitude in August; however, its day-to-day surface position varies greatly. As it shifts northward, the influence of the rotating globe - the Coriolis force - is great enough to permit a circulation to develop that can evolve into the tight, violent eddy (individual currents in a moving fluid) of a tropical cyclone. Weather satellites also have confirmed that some tropical cyclones may develop in connection with old polar troughs or upper level cold lows and have initial baroclinic (cold core) circulation.
In recent years, these latter systems have been designated as subtropical cyclones during the period they exhibit cold core characteristics. Although there is no full understanding of what triggers off a hurricane, it seems that some starter mechanism - an intruding polar trough, a tropical wave, an eddy from an active ITCZ - stimulates an area of continued deep convection, vertical air motion. Further development may occur when, for instance simultaneously:
a) depending on high low-level temperature and moisture content, enough water vapor in the ascending moist columns condenses (releasing large amounts of heat energy to drive the wind system),



Structure of a hurricane. Heights are greatly exaggerated compared to horizontal distances.

b) the vertical wind shear, the difference in air flow in the usually two layer structure of the tropical troposphere, remains below certain limits, to prevent ventilation of energy over a large area and, thus, allowing the vertical circulation to acquire greater organization,

c) the high altitude wind system supports divergence, carrying the vertical transport of exhaust air well away from the disturbance before it can sink to lower levels again,

d) depending on the northward latitude of the disturbance, the influence of the rotating globe - the Coriolis force - is great enough to permit the development of a cyclonic circulation.
The horizontal form of the disturbance then becomes the familiar cyclonic spiral, in which the movement of low and mid level air is counter clockwise, an embryo hurricane.
It is also believed that planetary wind systems, displaced northward, set up an essential large-scale flow which supports the budding storm, and that the development of a hurricane is often preceded by high-level warming and low- level inflow, in some balance that is not fully understood.

Classification of Atlantic Tropical Cyclones

Tropical cyclones are technically defined as non frontal low pressure synoptic scale*) systems that develop over tropical or subtropical waters and have a definite organized circulation. Further classification depends upon the wind speed near the center of the system. The terms, tropical depression, tropical storm, or hurricane are assigned depending upon whether the sustained surface winds near the center of the system are, respectively, 61 km/h, 62 to 117 km/h, 118 km/h or higher. More complete definitions are given in this table. Tropical cyclones are not archived (or named) unless they reach at least tropical storm strength.

The term sustained wind refers to the wind averaged over one minute. Shorter period gusts (or lulls) in the wind may be considerably higher (or lower) than the sustained wind.

Although the wind criteria defining the various stages of tropical cyclones are rather rigidly defined, the maximum sustained wind, however, often must be inferred from indirect evidence and a figure is subjectively assigned by the responsible analyst after considering all available information.

These operational constraints should be kept in mind. The extratropical stages of the cyclone tracks indicate that modification of the tropical circulation was started by movement of the cyclone into a non tropical environment. In this situation, the size of the circulation usually expands, the speed of the maximum wind decreases, and the distribution of winds, rainfall and temperature around the center become increasingly asymmetric. While these characteristic features develop some tropical features such as; a small area of strong often hurricane force winds near the center, the remnants of an eye and extremely heavy rainfall, may be retained for a considerable time. There are no wind speed criteria associated with the term extratropical. Usually wind speeds near the center of a storm gradually subside. In some cases however, Renton-suffocation of the system may occur when mechanisms conducive to extra tropical development offset the loss of the tropical energy source. If over land, these mechanisms may offset the dissipative effects of the increase in surface friction.

Subtropical cyclones are defined as non frontal low pressure systems comprising initially baroclinic (cold-core) circulations developing over subtropical water. Many of these eventually develop into purely tropical (warm core) systems, but others remain as subtropical.

Depending upon wind speed, two classes of subtropical cyclones are recognized either subtropical depressions or subtropical storms. The former have maximum sustained surface winds of 33 km/h and the latter 63 km/h. There is no upper wind speed limit associated with subtropical storms as there is with tropical storms. However, experience has shown that when and if surface winds in subtropical storms do reach or exceed 118 km/h, the system typically takes on sufficient tropical characteristics to be formally designated as a hurricane. Only in rare cases, such systems do associate themselves with hurricane force winds without attaining sufficient tropical characteristics. In this case, the term subtropical storm is retained.

*) Synoptic scale refers to large-scale weather systems as distinguished from local systems, such as thunderstorms. On rare occasions subtropical systems have evolved from tropical systems.

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Standard Definitions for Classification

Stage of Development	Criteria
Tropical Disturbance:	A discrete system of apparently organized convection originating in the tropics or subtropics, having a non-frontal migratory character and having maintained its identity for 24 hours or more. It may or may not be associated with a detectable perturbation in the wind field.
Tropical Wave:	A trough of cyclonic curvature maximum in the trade wind easterlies. The wave may reach maximum amplitude in the lower middle troposphere, or may be the reflection of an upper-troposphere cold low or an extension of a middle latitude trough toward the equator.
Tropical Depression:	The formative stages of a tropical (development) cyclone in which the maximum sustained wind (1 minute mean) is 61 km/h (38 mph, 33 knots) or less.
Tropical Storm:	A well organized warm core tropical cyclone in which the maximum sustained surface wind (1 minute mean) is in the range of 62 to 117 km/h (39-73 mph, 34-63 knots) inclusive.
Hurricane:	A stronger tropical cyclone in which the maximum sustained surface wind (1 minute mean) is 118 km/h (74 mph, 64 knots) or greater.
Tropical Depression:	The decaying stages of a tropical (dissipation) cyclone in which the maximum sustained surface wind (1 minute mean) has dropped to 61 km/h (38 mph, 33 knots).
Extratropical Cyclone:	Tropical cyclones modified by interaction with non-tropical environment. No wind speed criteria, may exceed hurricane force.
Post-tropical Cyclone:	A former tropical cyclone. This generic term describes a cyclone that no longer possesses sufficient tropical characteristics to be considered a tropical cyclone. Post-tropical cyclones can continue carrying heavy rains and high winds. Note that former tropical cyclones that have become fully extratropical, as well as remnant lows, are two classes of post-tropical cyclones.
Subtropical Cyclone:	A non-frontal low pressure system that has characteristics of both tropical and extratropical cyclones. This system is typically an upper-level cold low with circulation extending to the surface layer and maximum sustained winds generally occurring at a radius of about 160 km/ 100 miles or more from the center. In comparison to tropical cyclones, such systems have a relatively broad zone of maximum winds that is located farther from the center, and typically have a less symmetric wind field and distribution of convection.
Subtropical Depression:	A subtropical cyclone in which the maximum sustained surface wind (1-minute mean) is 61 km/h (38 mph, 33 knots).
Subtropical Storm:	A subtropical cyclone in which the maximum sustained surface wind (1-minute mean) is 62 km/h (39 mph, 34 knots).

Climatology of Atlantic Tropical Cyclones

Wind and Pressure

At lower levels, when a hurricane is most intense, winds on the rim of the storm follow a wide pattern, like the lower currents on the rim of a whirlpool; like those currents, these winds accelerate as they approach the central vortex.
This inner band is the eyewall, where the storm's worst winds are felt. Hurricane winds are produced as all winds are, by difference in atmospheric pressure, or density. The pressure gradient - the rate of pressure change with distance - produced in hurricanes is the sharpest in the atmosphere, excepting only the pressure change believed to exist across the narrow funnel of a tornado.

Atmospheric pressure is popularly expressed as the height of a column of mercury that can be supported by the weight of the overlying air at a given time. In the tropics it is generally close to 1015 millibars*, approximately 30 inches of mercury, under normal conditions.
Hurricanes drop the bottom out of these normal categories. Hurricane Gilbert (1988) had a record low central pressure of 885 mb; the Labor Day hurricane that struck the Florida Keys in 1935 had a central pressure of only 892 millibars. The change is swift: pressure may drop more than 30 millibars an hour, with a pressure gradient of 3 millibars per kilometer.
At the center of the storm is a unique atmospheric entity, and a persistent metaphor for order in the midst of chaos - the eye of the hurricane. It is encountered suddenly. From the heated tower of maximum winds and thunderclouds, one bursts into the eye, where the winds diminish to less than 25 km/h. Penetrating the opposite wall, one is abruptly in the worst of winds again.

Storm Surge

A mature hurricane orchestrates more than a million cubic kilometers of atmosphere. Over the deep ocean, waves generated by hurricane winds can reach heights of 15 meters or more. Under the storm center the ocean surface is drawn upward like water in a giant straw, forming a mound some 30 centimeters higher than the surrounding ocean surface. This mound translates into coastal surges of 6 meters or more. Besides the surge, massive swells pulse out through the upper layers of the sea.
This, of course, also influences the marine environment. The ocean is disturbed to depths of 500-1000 meters, and "remembers" a hurricane passage with internal waves that persists for weeks after the storm has gone. It is also demonstrated that a passing hurricane can be felt deep in the sea floor sediments.
While a hurricane lives, the transaction of energy within its circulation is immense. The condensation heat energy released by a hurricane in one day can be equivalent to the energy released by fusion of four hundred 20-megaton hydrogen bombs.
One day's released energy, converted to electricity, could supply the United States' electrical needs for about six months.

*) Weather maps show atmospheric pressure in hectoPascals (hPa) which are equivalent to millibars, a thousandth of a bar, the unit of pressure equal to one million dynes per square centimeter.

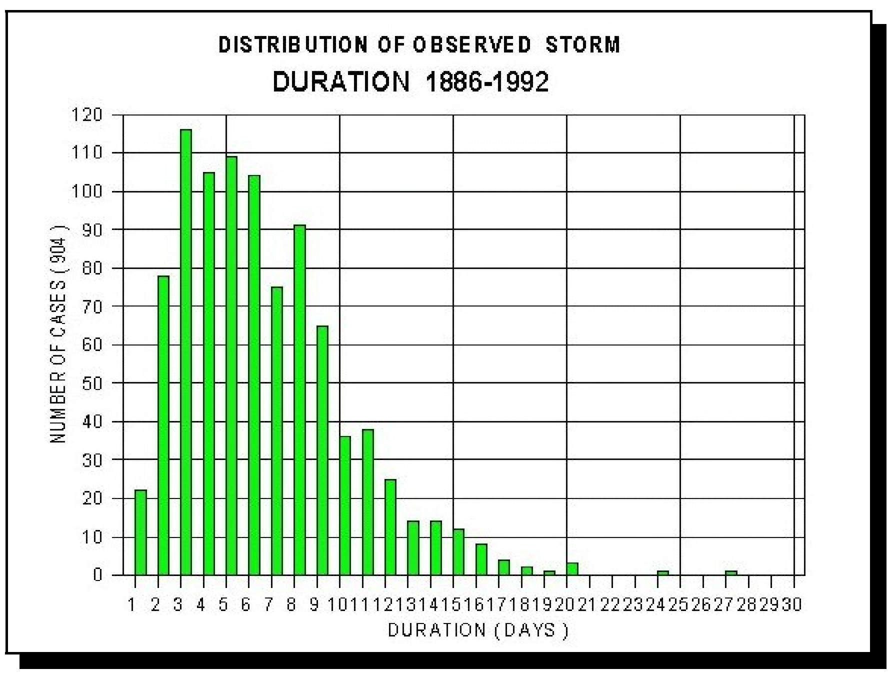
Steering

The movement of Atlantic tropical cyclones is more or less controlled by the quasi-permanent Bermuda-Azores anticyclone, or high pressure system. Over the tropical Atlantic the storm is generally driven by the easterly trade wind flow in which it is embedded. As long as this westerly drift is slow - less than 30-35 km/h - the young hurricane may intensify. More rapid forward motion generally inhibits intensification in the storm's early stages. To the west of the Atlantic anticyclone the steering currents take the storm away from its tropical breeding ground. The trend is a clockwise curve over the Caribbean, the Gulf of Mexico and the coastal waters of the eastern United States into the temperate latitudes. There are some storms which may move along at better than 90 km/h, but the end usually comes swiftly. Colder air penetrates the cyclonic vortex; the warm core cools, and acts as a thermal brake on further intensification. Water below 27 degrees Celsius does not contribute much energy to a hurricane. Even though some large hurricanes may travel for days over cold North Atlantic water, all storms are doomed once they leave the warm tropical waters which sustain them.

Over land, hurricanes break up rapidly. Cut off from their oceanic source of energy, and with the added effects of frictional drag, their circulation rapidly weakens and becomes more disorganized. Torrential hurricane rains, however, may continue even after the winds are much diminished, or combine with existing temperate zone disturbances. Many storms moving up the coast of the Northeastern United States are in the throes of this transformation when they strike, and large continental lows are often invigorated by the remnants of storms born over the tropical sea.

Duration of Tropical Cyclones

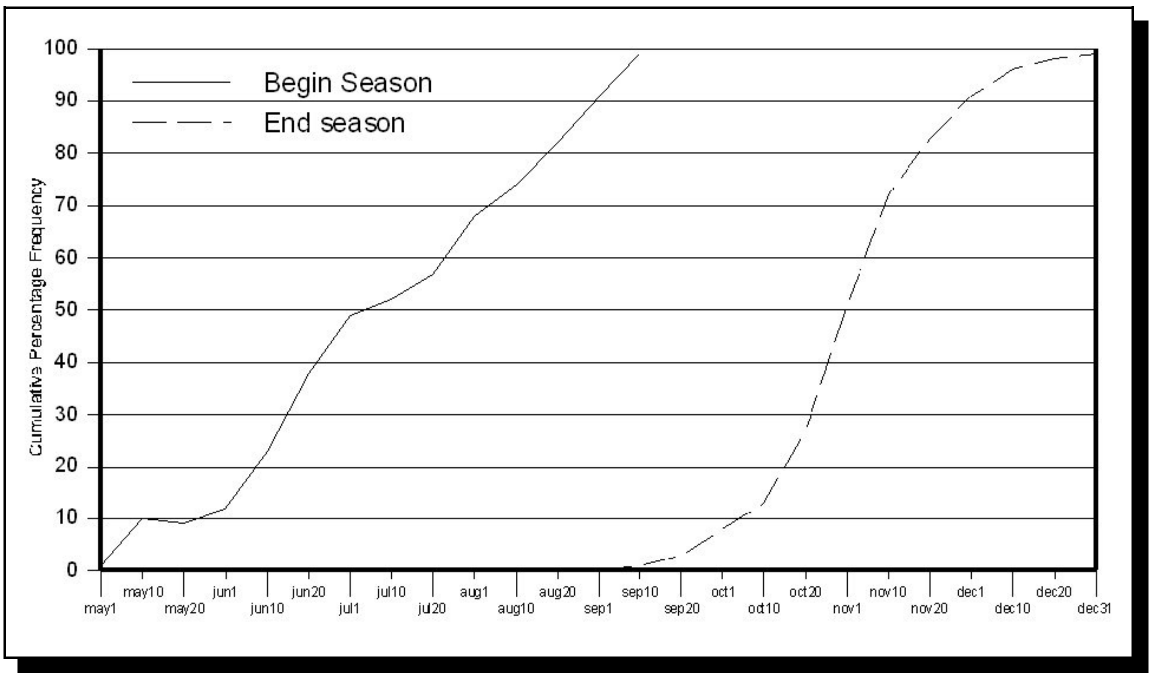
Based on all Atlantic tropical cyclone tracks from 1886 through 2013, the duration of a tropical cyclone, including the depression stage, averages about eight days but may vary from less than 2 days to as many as 30 days (Ginger, 1971).
Very brief storms typically form in the Gulf of Mexico and dissipate rapidly over adjacent land areas, whereas the long-duration storms include mainly those which are formed over the Eastern Atlantic, travel westward to recurve just before reaching the United States and then move northeastward across the open Atlantic.



Distribution of observed duration (number of days, including depression stage and excluding extra tropical stage) of Atlantic tropical cyclones, 1886-1992. Average and standard deviation are 7.5 and 3.7 days, respectively.

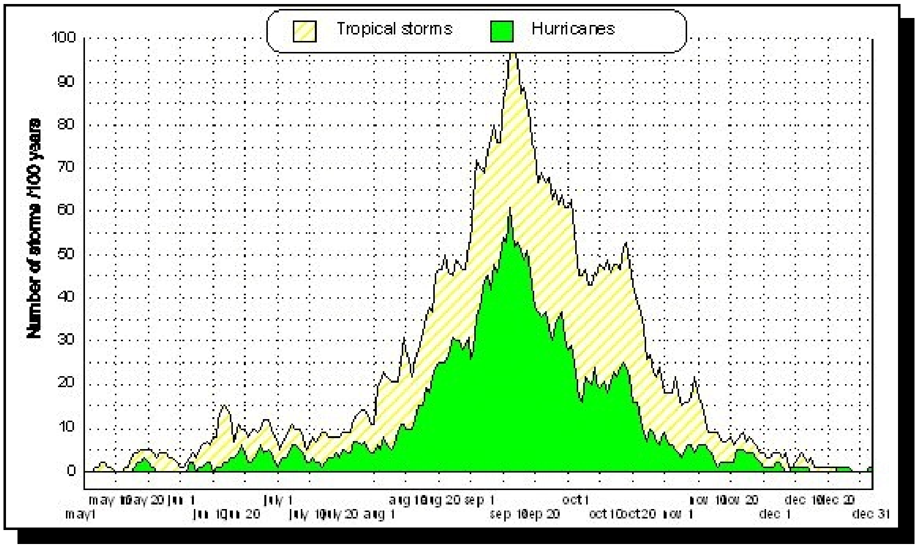
Hurricane Season

The "official" Atlantic hurricane season extends from June 1 through November 30. However, as seen from the figure, the season occasionally begins or ends outside of this period.
The figure presents a cumulative percentage frequency distribution of the date of detection of the first and the date of dissipation of the last tropical cyclone of storm or hurricane intensity for each season from 1886 through 2013.
The median (midpoint of the distribution) beginning date is June 26, the median ending date is October 29. There are no statistical relationships between the beginning and ending dates of the tropical cyclone season; that is, seasons which begin early do not necessarily end early (or late) or the opposite.



Cumulative percentage frequency distribution of beginning and ending dates of Atlantic tropical cyclone season, 1886 through 2013. (Dates are of first and last recorded position with at least tropical storm strength) Data have been smoothed using a 9-day moving average.

As seen from the figure illustrating the incidence of tropical cyclones over the North Atlantic basin on a daily basis for the 6-month period that covers the principal season, the peak in the annual hurricane season runs from mid August till mid October with its maximum around September 10.



Intra-seasonal variations in the 100-year frequency of tropical cyclones occurrences. Lower bar is for hurricanes and upper bar is for hurricanes and tropical storms combined. Summary is based on period of record, 1886-2013.

Monthly and Annual Frequencies of Atlantic Tropical Cyclones

The number of storms occurring in any given year varies widely. Insofar as storms reaching at least tropical storm strength are concerned, there were two years, 1890 and 1914, that observed but one storm while 21 tropical storms or hurricanes occurred in 1933 and even 28 in record breaking 2005. There were no storms that reached hurricane strength in both 1907 and 1914 while 15 hurricanes occurred in 2005, 12 in 1969 and 2010, and 11 in 1995.

One may question the adequacy of these data. After the mid 1940's, when aircraft reconnaissance began, it is unlikely that even weak, short duration storms have been undetected. This was not always the case: some small, weak tropical storms may have gone undocumented in the earlier years, and storms that were detected could have been misclassified as to intensity.

In addition to observational problems, there is a strong possibility that other natural trends exist in the frequency of tropical cyclones. For example due to the effect of large-scale anomalies in sea surface temperature. Upward or downward trends in the frequency of tropical cyclones are illustrated in the following table.

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Total and average number of tropical cyclones (excluding depressions and including subtropical systems) beginning in each month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1886 - 1992													
Tropical Storms and Hurricanes	1	1	1	1	14	56	68	217	308	189	42	6	904
Average over Period	*	*	*	*	0.1	0.5	0.6	2.0	2.9	1.8	0.4	0.1	8.4
Hurricanes Only	0	0	1	0	3	23	35	151	193	97	21	3	527
Average over Period	0.0	*	0.0	*	0.2	0.3	1.4	1.8	0.9	0.2	*	*	4.9
1910 - 1944													
Tropical Storms and Hurricanes	0	0	0	0	0	7	7	24	39	26	6	0	109
Average over Period	0.0	0.0	0.3	0.0	0.0	0.3	0.3	1.1	1.9	1.2	0.3	0.0	5.2
Hurricanes Only	0	0	0	0	0	4	4	21	29	12	4	0	74
Average over Period	0.0	0.0	0.0	0.0	0.0	0.2	0.2	1.0	1.4	0.6	0.2	0.0	3.5
1944 - 1992													
Tropical Storms and Hurricanes	1	1	0	1	8	26	38	122	171	82	21	4	475
Average over Period	*	*	0.0	*	0.2	0.5	0.8	2.5	3.5	1.7	0.4	0.1	9.7
Hurricanes Only	0	0	0	0	2	10	17	78	109	52	11	2	281
Average over Period	0.0	0.0	0.0	0.0	*	0.2	0.3	1.6	2.2	1.1	0.2	0	5.7

Asterisk (*) indicates less than 0.05 storms

The first period begins with the year when it was possible to distinguish between tropical storms and hurricanes; the period 1910 through 1930 had a minimum in frequency with an average of only about five storms per year. The last period begins with the introduction of organized aircraft weather reconnaissance.

The averages for the three periods appearing in this table show substantial differences in the monthly and annual frequencies.

The period 1944 through 2010 probably best represents Atlantic tropical cyclone frequencies as they currently exist.

Atlantic Tropical Cyclone Basin, Areas of Formation

Seasonal shifts in the principal areas of tropical cyclone formation over the Atlantic basin have been recognized for many decades. Early season tropical cyclones are almost exclusively confined to the western Caribbean and the Gulf of Mexico. However, by the end of June or early July, the area of formation gradually shifts eastward, with a slight decline in overall frequency of storms. By late July, the frequency gradually increases, and the area of formation shifts still farther eastward.

By late August, tropical cyclones form over a broad area which extends eastward to near the Cape Verde islands. The period from about August 20 through about September 15 encompasses the maximum of these "Cape Verde" type storms, many of which traverse the entire Atlantic Ocean. Hurricanes like Allen (1980), Hugo (1989), Luis (1995), Georges (1998) and Ivan (2004) are typical examples. After mid-September, the frequency begins to decline and the formative area retreats westward. By early October, the area is generally confined to longitudes west of 60 West, and the area of maximum occurrence returns to the western Caribbean. In November, the frequency of tropical cyclone occurrence decreases further.

Identification of Atlantic Tropical Cyclones

Before 1950, there was no formal nomenclature for the identification of cyclones. Noteworthy storms were informally designated by such descriptive terms as the "Great Barbados hurricane", "San Felipe hurricane", "Labor Day storm", etc.
Official naming of Atlantic tropical storms and hurricanes by the Regional Hurricane Center in Miami, Florida, began in 1950. Initially, the 1950 vintage phonetic alphabet (Able, Baker, Charlie, and so on) was used. However, for the 1953 season, the practice of using English women's names, first used in the western Pacific during World War II when American wartime when weathermen informally identified individual storms by name of their wives and sweethearts, was introduced. This convention used an alphabetic series of names starting with A, that changed each year and continued until 1979.
With the 1979 season, the annual session of the WMO Regional Hurricane Committee (in which all the countries of the region are represented and which acts as a regional forum for matters of common interest with respect to hurricane preparedness and disaster prevention) decided to use a 6-year rotating sequence of alphabetical series with alternatively men's and women's names in the three regional languages, Spanish, English and French. However, if a hurricane acquires special reasons (for instance by causing many deaths and/or extensive damage), its name may be retired and a replacement name selected.

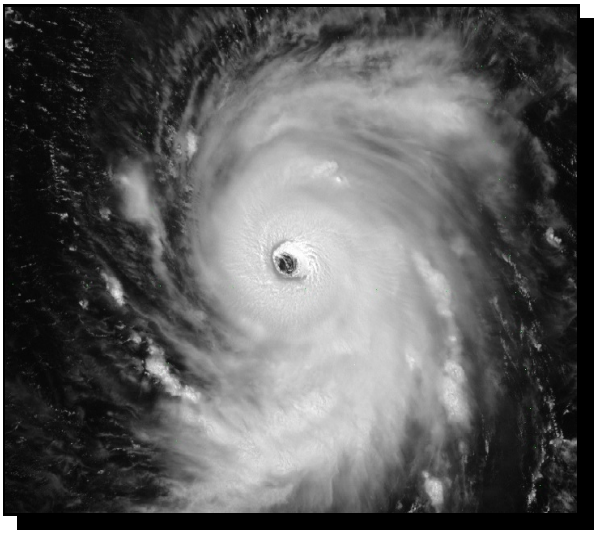
Names to be Used for Named Tropical Cyclones in the Caribbean Sea, the Gulf of Mexico and the North Atlantic Ocean.

2015	2016	2017	2018	2019	2020
Ana	Alex	Arlene	Alberto	Andrea	Arthur
Bill	Bonnie	Bret	Beryl	Barry	Bertha
Claudette	Colin	Cindy	Chris	Chantal	Cristobal
Danny	Danielle	Don	Debby	Dorian	Dolly
Erika	Earl	Emily	Ernesto	Erin	Edouard
Fred	Fiona	Franklin	Florence	Fernand	Fay
Grace	Gaston	Gert	Gordon	Gabrielle	Gonzalo
Henri	Hermine	Harvey	Hélène	Humberto	Hanna
Ida	Ian	Irma	Isaac	Imelda	Isaias
Joaquin	Julia	José	Joyce	Jerry	Josephine
Kate	Karl	Katia	Kirk	Karen	Kyle
Larry	Lisa	Lee	Leslie	Lorenzo	Laura
Mindy	Matthew	Maria	Michael	Melissa	Marco
Nicholas	Nicole	Nate	Nadine	Nestor	Nana
Odette	Otto	Ophelia	Oscar	Olga	Omar
Peter	Paula	Philippe	Patty	Pablo	Paulette
Rose	Richard	Rina	Raphael	Rebekah	René
Sam	Shary	Sean	Sara	Sebastien	Sally
Teresa	Tobías	Tammy	Tony	Tanya	Teddy
Victor	Virginie	Vince	Valerie	Van	Vicky
Wanda	Walter	Whitney	William	Wendy	Wilfred

Hurricane Preparedness and Disaster Prevention

Hurricanes are the unstable, unreliable creatures of a moment in our planet's natural history. But their brief life ashore can leave scars that never quite heal. Most of a hurricane's destructive work is done by the storm surge, the wind and the flood producing rains.
Hurricane winds can be the least destructive of these. These winds are a force to be reckoned with by coastal communities deciding how strong their structures should be. As winds increase, pressure against objects mounts with the square of the wind velocity. Without a building code which, for example, increases the cost of construction by only 6 per cent but reduces damage by 60 per cent for sustained winds up to 240 km/h, this added force is enough to cause failure to many structures. Winds also carry a barrage of debris that can be quite dangerous.
Floods from hurricane rainfall are quite destructive. A typical hurricane brings 150 to 300 mm of rainfall to the area it crosses, and some have brought much more. The resulting floods may cause great damage and loss of life, especially in mountainous areas, where heavy rains mean flash floods. However, the hurricane's worst killer comes from the sea, in the form of storm surge, which claims nine of every ten victims in a hurricane. The advancing storm surge combines with the normal astronomical tide to create the hurricane storm tide. In addition wind waves are superimposed on the storm tide. This buildup of wave and current action associated with the surge can cause severe flooding and extensive damage in exposed low-lying coastal areas.
Water weighs some 1000 kilograms per cubic meter; extended pounding by frequent waves can demolish any structure not specifically designed to withstand such forces.
In addition, many buildings withstand hurricane winds until, their foundation undermined by erosion of storm surge currents along the coast, they are weakened and fail.

The damage swath from a major hurricane can cover more than 200 kilometers of coastline. However, the pattern of wind, rainfall, storm surge and associated damage are rarely symmetrical about the storm track. Wind and storm surges are typically higher in the right semicircle of a storm (as viewed toward the direction of motion) where the storm's motion and wind are complementary, but other meteorological and geographical factors also contribute to asymmetries. Anyhow, since storm tracks in the eastern Caribbean are generally from East or East Southeast to West or West Northwest, this means for the islands of the Dutch Caribbean that the most severe weather will be encountered when the storm is expected to pass within a short distance south of the islands.
With the introduction of continuous weather satellite surveillance in the sixties, in addition to conventional data, aircraft reconnaissance flights, weather radar and high speed communications, an efficient regional forecasting and early warning system has been developed over the years.
There is a high probability that the center (eye) of the storm could be located within 50 kilometers of its actual position and the intensity determined to within 20 km/h of its actual intensity. Whilst the accuracy of landfall prediction 24 hours or more ahead, is not as precise as would be desired, continuous monitoring of the storm's approach to coastal areas enables the forecast to be constantly updated and refined in the hours leading up to landfall. The aim is usually to provide at least 12 daylight hours of lead time to the population.



Satellite picture of hurricane Georges taken on September 19, 1998 while still located rather far East of the Northeastern Caribbean islands. The eye has the so-called "Stadium Effect", named after its appearance like a ring of grand stands around a football field.

The efficiency of the warning system should not, however, be a cause for complacency. Disasters still occur with distressing regularity.
Another requirement in a tropical cyclone warning service is, in some respects, more complex but should receive high priority. It concerns the individual and the preventive measures to protect human life and reduce economic losses.
A prime necessity is that each person fully understands the dangers and is able and ready to respond in a way that will limit their impact. Thus, local arrangements must be adequate and constantly reviewed (at least immediately prior to the hurricane season) to provide for everyone to be warned, for the availability of shelters and up-to-date evacuation plans, and when a cyclone has struck, for the relief, rehabilitation and reconstruction measures that will accelerate a rapid return to normal conditions. In short, no effort should be spared to increase the awareness of the adverse impact of natural disasters and to counteract the increasing vulnerability that accompanies the growth of population and the development of the local economy.

Hurricane Climatology of the Dutch Caribbean

The ABC Islands

Aruba, Bonaire and Curaçao are on the southern fringes of the hurricane belt. They are not outside the hurricane belt, as many consider. History learns that roughly once every 100 years considerable damage is experienced by tropical cyclones passing over or just south of the islands. Although the hurricane experience level for the islands may be regarded as very small, well known is the minor hurricane which passed just south of Curaçao on September 23, 1877 causing an estimated structural damage of US$ 2 million, mainly to the coastal section of Willemstad. A nunnery was completely washed away (remnants still visible at low tide), many ships were lost and at least 70 persons drowned. The lowest barometer reading at Willemstad was observed at 15:30 UTC on September 23 (UTC = local time + four hours in Eastern Caribbean Area) with 995.4 millibars. A ship sailing south of Curaçao reported a lowest pressure of 988.8 millibars.

On the average, once every four years a tropical cyclone occurs within a radius of 150 kilometers, but mostly passing to the north of the islands without causing serious bad weather. Even the immediate effects of major hurricane Hazel, of which the center passed approximately 90 kilometers to the north on October 7, 1954, with maximum sustained winds near the center of 190 km/h, were confined to observed maximum winds of 50 km/h with gusts to 90 km/h, and the damage, an estimated US$ 350.000,-, resulted mainly from flash floods due to heavy rainfall (48 hours averages: Aruba approx. 250 mm, Bonaire and Curaçao approx. 125 mm).

Recent Storms

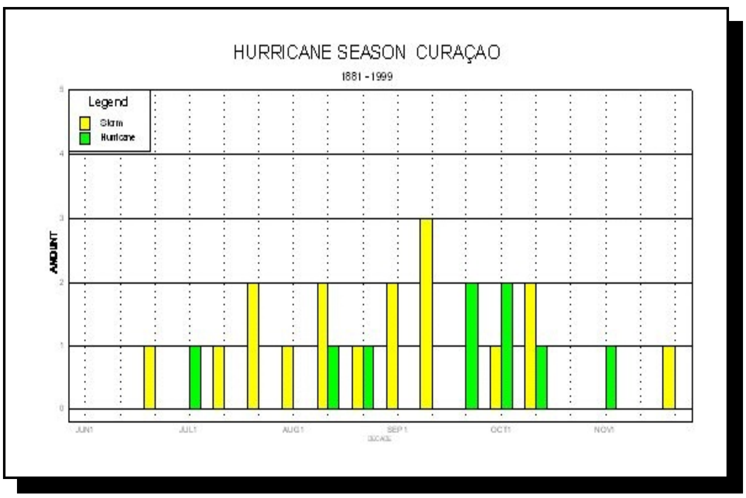
The most significant events in the past few years were related to tropical storms Joan in 1988, Bret in 1993, Cesar in 1996 and hurricanes Ivan in 2004, Emily in 2005, Felix in 2007, Tropical Storms Omar in 2008 and Tomás in 2010.

Tropical storm Joan, which passed just south of the islands on October 16, 1988, caused an estimated structural damage of approximately US$1.5 million, mainly by blown off roofs and by rough seas pounding exposed harbor and beach facilities.

Excessive rains in the aftermath of Joan additionally caused widespread flooding over the islands during several days. Lowest barometer reading at the airport was observed at 17:00 UTC with a value of 1001.0 hPa. Maximum observed sustained winds were however confined to 65 km/h with gusts to 90 km/h.

Tropical storm Bret passed as a minimal tropical storm south of the islands over northern Venezuela on August 8, 1993 causing some damage to coastal facilities due to rough sea conditions and also limited wind damage. On all three islands wind gusts of over 75 km/h were recorded. The heavy rainfalls associated with Bret were concentrated over the northern coastal areas of Venezuela causing more than 100 deaths due to landslides.

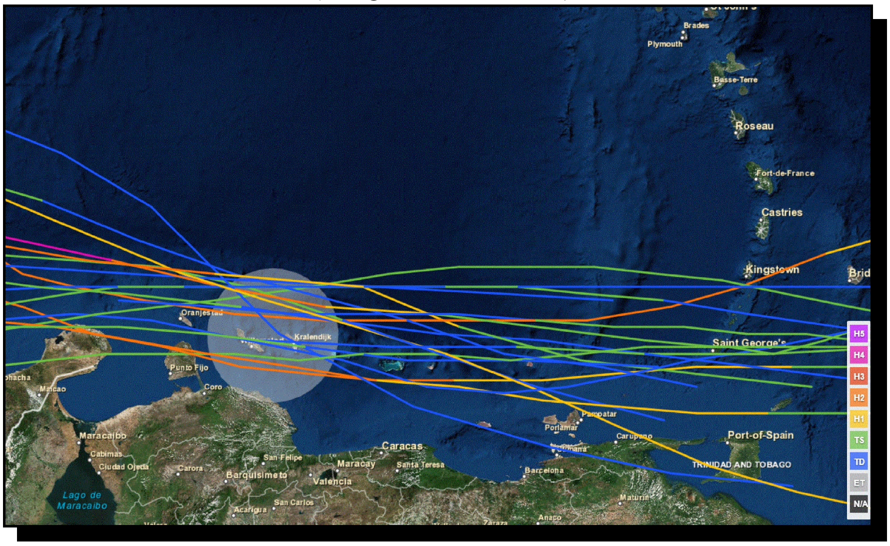
Tropical storm Cesar developed on July 25, 1996 between Bonaire and Curaçao. Later analysis showed that this system became a tropical depression a day earlier near Margarita, Venezuela. It moved over Curaçao near midday and caused southeasterly gusts up to 93 km/h. That resulted in very rough seas around this island. One imprudent swimmer drowned as a result of this. Elsewhere on all three ABC-Islands, only minor damage was caused to roofs and trees.



Number of tropical storms (yellow) and hurricanes (green) passing within 100 N.M. radius, in consecutive 10-day periods 1881-1995.

Tropical Cyclones passing within 60 nautical miles of Bonaire and Curaçao

(through December 31, 2013)



Extremely dangerous hurricane Ivan on September 7, 2004 became a serious threat for the ABC Islands and a Hurricane Warning was issued on that day. Its eye passed during the late evening of September 8 and the early morning of September 9 at a distance of approximately 130 km north of these islands. Although the destructive winds failed to impact the ABC Islands, the swells it generated were large enough to batter several constructions on its coasts. The greatest damage however was caused in Aruba during the early morning of September 10. A developing spiral band of the hurricane caused very heavy rain over this island which resulted in significant flooding in several locations and material damage at a cost of at least two million florins.

Less than a year later, hurricane Emily also became a threat on July 14, 2005, when it entered the southeastern Caribbean Area while moving in a west-northwesterly direction. A Tropical Storm Warning was issued that morning and the hurricane made its closest approach to the ABC Islands during the early morning of July 15 at a distance of about 175 kilometers. As was the case with Ivan, the potentially damaging tropical storm force winds stayed just north of the islands.

Hurricane Felix was the first tropical cyclone in more than a hundred years in which its center made a closest approach to these islands of less than 100 kilometers. This system quickly strengthened from a tropical depression on August 31, 2007 to a category five hurricane during the evening of September 2. Once more however, the wind field was rather small and the damaging winds of at least tropical storm intensity stayed mainly offshore. The only effects caused by Felix on the ABC Islands were locally heavy rains and rough seas.

Tropical storm, later hurricane, Omar developed well north of the ABC Islands but it had an unusually large wind field, especially south of its center. Strong southwesterly winds with gusts to gale force blew over these islands and large waves from the same direction battered mainly the south and west facing shores. That led to significant damage to some small vessels and coastal facilities and also caused significant beach erosion.

Tropical storm Tomás developed late October 2010 and became a hurricane when it was located near St. Vincent on October 29. It weakened to a minor tropical storm on November 1 and the center passed about 120 kilometers north of the ABC Islands, later that day. A feeder band developed during the early evening of the same day and barely moved throughout that night. The result was a persistent heavy thunderstorm activity over mainly the southeastern half of Curaçao and parts of Bonaire. In Curaçao, this heavy rain led to a couple of deaths and an estimated flood damage of about US$200 million.

See Attachment I - Tropical cyclones passing within 100 N.M. of 12.5N, 69.0W through December 31, 2014.

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The SSS Islands

Saba, St. Eustatius and St. Maarten are located within the hurricane belt. Almost every year at least one tropical cyclone occurs within a range of 100 miles and on the average once every 4-5 years hurricane conditions are experienced. Refer to Attachment II - Tropical cyclones passing within 100 N.M. of 17.5N, 63.0W through December 31, 2014.
The most recent hurricanes to cause considerable damage to the islands were the hurricanes Omar (2008), José (1999), Lenny (1999), Georges (1998), Luis (1995), Marilyn (1995), Hugo (1989), Donna (1960) and Dog (1950). Especially the damage caused by hurricane Luis was extensive.

Hurricane Donna and other past hurricanes

The center of hurricane Donna passed right over the island of St. Maarten during the night of September 4-5, 1960 with maximum sustained winds of 200 km/h and a lowest barometer reading of 952 millibars. Hurricane Dog (September 1, 1950) passed with maximum observed winds of 185 km/h and a lowest barometer reading of 978.7 millibars. Detailed particulars about the damage caused by hurricane Donna are not readily available.
It is known that it took several days before radio communications were restored. The wind tower was struck down after indicating for more than one hour its maximum of 150 km/h. The damage estimated with hurricane Dog was about US$ 70.000,- without loss of lives. Clearly the damage potential has increased considerable over the recent years, considering the almost 20-fold population growth (December 1950: 1478, December 1988: 26994). Worth mentioning are also the developing hurricane Eloise (September 15, 1975) and minor hurricane Frederic (September 3, 1979), particularly because of the prolonged extensive flooding from their associated torrential rainfall of more than 250 mm within 24 hours. Hurricane Frederic also took the lives of 7 seamen aboard a Japanese fishing vessel that wrecked in the harbor of Philipsburg.

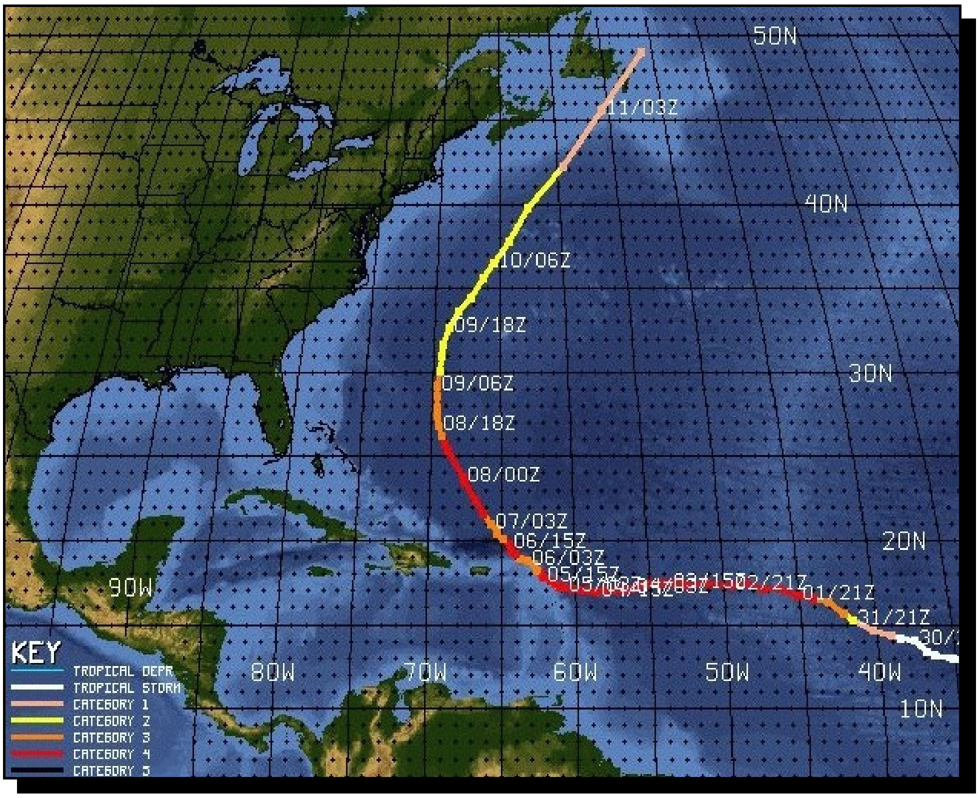
Hurricane Hugo

The center of hurricane Hugo passed at approximately 70 km south of St. Eustatius and Saba in the early afternoon of September 17, 1989, with maximum sustained winds of 225 km/h and a lowest barometer reading of 947 millibars. Thanks to timely warnings no lives were lost, but material damage was quite extensive, conservatively estimated in excess of US$ 10 million. A large number of houses and public buildings were more or less severely damaged, as were the piers on both islands. Most of the trees were uprooted and the islands were left nearly bare of all vegetation. Electric power and all communications were disrupted for a considerable time.
Although St. Maarten escaped the full brunt of the hurricane, still considerable damage was experienced to roofs and exposed beach and harbor facilities.

Hurricane Luis

The center of hurricane Luis passed at approximately 55 km north of St. Maarten in the early evening of September 5, 1995, moving in a west-northwesterly direction. While the center of hurricane Luis was just north of St. Maarten, the maximum sustained winds near the center and the lowest barometric reading of the hurricane, were respectively 140 mph (205 km/h) and 939 millibars. The strongest wind gust recorded at the Princess Juliana Airport was 114 mph (183 km/h) at 18:30 local time and the lowest barometric reading recorded at the airport was 963 millibars. From the 4th of September through the 6th, approximately 200 mm of rainfall was recorded. Locally on the island, this amount was exceeded to values between 200 mm and 250 mm.
Fortunately, due to a well-functioning warning system and very timely warnings, only very limited casualties were experienced (official records: two deaths). The damage, especially on the island of St. Maarten, was extensive. The total damage was estimated to be approximately 1 billion US dollars (direct and indirect). Over 90% of all construction was damaged or had been completely destroyed. Nearly all power and telephone lines were damaged and out of operation which left the island for several days without communication with the rest of the world.

The shores of the Simpson Bay Lagoon remained littered with pleasure vessels after the passage of hurricane Luis. Saba and St. Eustatius experienced considerably less damage than St. Maarten because the most intense portion of the hurricane remained to the north of these islands. In the aftermath of Hurricane Luis (after just ten days), these three islands were once again affected by a hurricane (Marilyn).



Track of hurricane Luis. 01/21Z stands for September 1 at 2100 UTC (Universal Time Coordinated) or GMT (Greenwich Mean Time) which is equal to 17:00 hours Atlantic Standard Time.
Map courtesy of the University of Wisconsin.

Hurricane Marilyn

The center of hurricane Marilyn passed at approximately 65 km south of St. Eustatius and Saba on the 15th of September 1995 moving in a west northwesterly direction. The maximum sustained wind speed recorded at the Juliana Airport was limited to only 43 mph and a maximum wind gust of 61 mph was recorded on the 15th at approximately 11:45 local time. Hurricane force winds did not occur on St. Maarten. Taking into consideration that the center of Marilyn passed at a much closer distance from St. Eustatius and Saba, it is highly probable that on these islands wind conditions of hurricane force must have been experienced. Recorded meteorological information on the islands of Saba and St. Eustatius is not available. The damage caused by hurricane Marilyn was mainly due to high seas and rainfall. Due to the position of the center of hurricane Marilyn, the south coast of St. Maarten experienced very rough seas. These rough seas caused considerable damage to the coast and coastal installations (e.g. electricity plant factory of GEBE) than did hurricane Luis. The related rainfall caused additional problems to buildings and houses which were already roofless because of hurricane Luis.

Hurricane Georges

Hurricane Georges, a category three hurricane, affected the Windward Islands of the Dutch Caribbean on September 21, 1998. The eye of the hurricane passed right over the islands of Saba and St. Eustatius and 45 miles or 70 km south of St. Maarten. The maximum sustained wind speed, at that time, was 110 mph

or 175 km/hr. The maximum wind gust recorded on Saba was 163 mph or 263 km/hr.
A large number of buildings and houses on the three islands was severely damaged due to these extremely strong hurricane winds. Electricity and telecommunications were out for several days.
The estimated total damage, on the three islands, was between US$70 and 80 million.
Due to the early warnings and the excellent preparations, on all three islands, there were no deaths and only a very limited number of injured persons during the passage of hurricane Georges.

Hurricane José

The eye of Hurricane José, a category two hurricane, passed over the island of St. Maarten on Wednesday, October 20, 1999. The maximum sustained winds measured at the Princess Juliana Airport were 65 knots (75 mph). The maximum wind gust was 87 knots (100 mph). The wind damage was minimal. Some houses had their roofs blown off and a few yachts were thrown on shore. Most of the damage came from the heavy rainfall which persisted through Friday afternoon. Heavy flooding occurred in low lying areas of the island. The authorities estimated the damage to be around 7.5 to 8.5 million US$. One person was killed due to a mud slide.

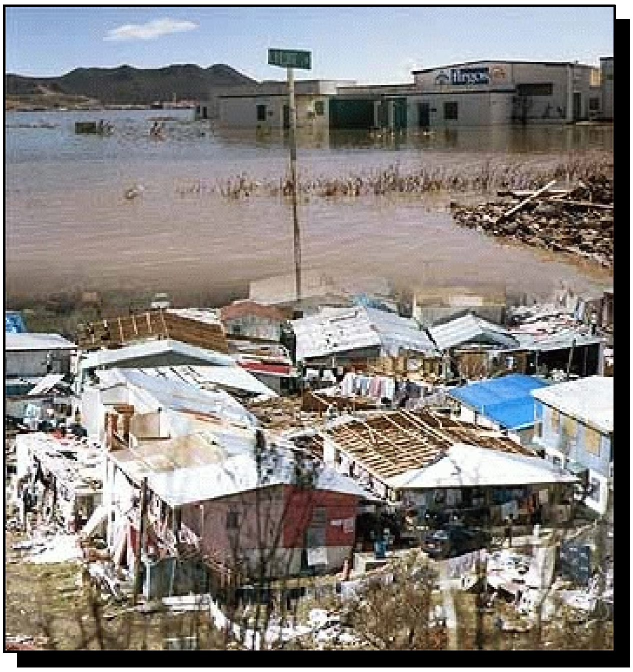
Hurricane Lenny

Hurricane Lenny, an extremely rare hurricane, formed south of Jamaica and moved eastward toward the Lesser Antilles. Hurricane Lenny is the first hurricane ever to strike the Lesser Antilles from the west. On Thursday, November 18, 1999, the center of hurricane Lenny passed just a few miles west of St. Maarten moving in a northeasterly direction as a category three hurricane with maximum sustained winds of 115 mph. Generally St. Maarten remained in the eastern and southeastern part of the eye wall.

Unusual track of Lenny (from west to east). The times (2100Z) are given in Coordinated Universal Time (GMT) which is four hours ahead of the local Atlantic Standard Time.
Map courtesy of the University of Wisconsin.

During the night the hurricane slowed down and resumed a more southeasterly movement. This time the eye of the hurricane passed just a few miles east of St. Maarten. St. Maarten experienced the effects of the western part of the eye wall. Lenny was now a strong category two hurricane.

For a 36-hour period, from Wednesday, November 17, 8 P.M. to Friday, November 19, 8 A.M. St. Maarten experienced tropical storm conditions with three periods where maximum sustained winds were above hurricane force.



Wind and water damage caused by Lenny near the Salt Pond in Sint Maarten.
Picture courtesy of Amigoe.

The highest sustained wind speed measured at the Princess Juliana Airport was 84 mph and the maximum gust was 104 mph (167 km/h) at 01:32 hours Friday, November 20, 1999. The lowest barometric pressure was 972.1 mb.
Lenny's approach from the west caused an unprecedented sea wave impact on the westward facing coastline and harbors of St. Maarten. Wave height estimates are between 10 to 16 feet.

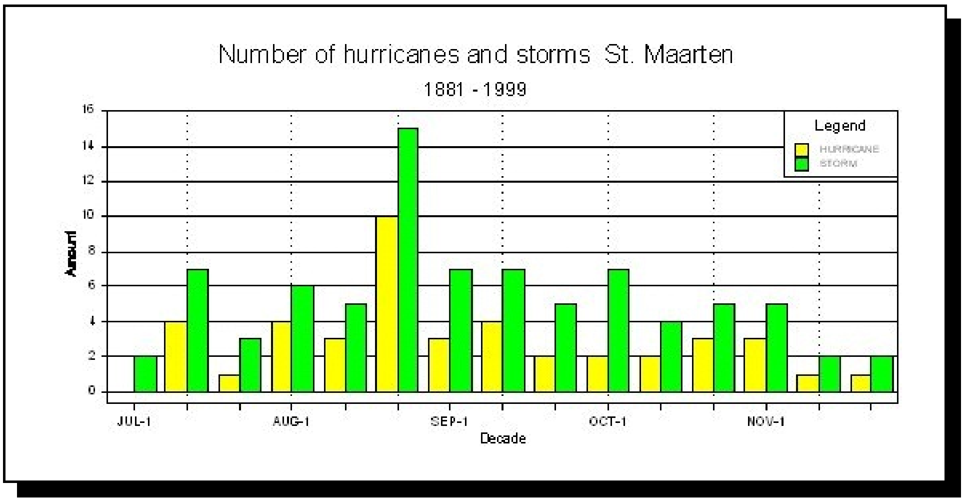
The total precipitation amounts over the 36-hour period of Lenny's presence over and around the Lesser Antilles reached record amounts. On the French side of St. Maarten rainfall measurements at the Gendarmerie totaled 34.12 inches (866.6 mm) and at Marigot 26.1 inches (662.9 mm). At the Princess Juliana Airport the total amount over 36-hours was 27.4 inches (696.0 mm) The excessive amounts of rainfall caused mud slides and severe flooding. For many locations heavy rainfall was the primary damage impact of hurricane Lenny. There were three casualties in St. Maarten during the passage of hurricane Lenny.
The islands of Aruba, Bonaire and Curaçao all experienced heavy surf conditions along their southern coastlines as Lenny passed many miles north of the islands. During the period between late Monday evening (November 15) and Wednesday morning (November 17), swells caused severe beach erosion and damage to small vessels and beach structures.

Hurricane Omar

Hurricane Omar, also a rather rare hurricane, developed as a tropical depression not far north of the ABC Islands on October 13, 2008 and then after stalling for a couple of days, moved quickly toward the northeast during the days thereafter. It also intensified rapidly from a category one to a category three hurricane during the early morning of October 16. As it moved along the SSS Islands, the surface winds shifted from east to south and then to the southwest, while increasing gradually in speed. The strong southwesterly winds caused high waves and a storm surge, which resulted in damaging coastal flooding over sections of these islands. During the passing of the hurricane, the center remained well away from the islands, so that mainly tropical storm conditions were experienced, while the islands remained outside the area of hurricane winds. Nevertheless, widespread damage was experienced to coastal facilities, buildings and infrastructure. The heaviest rain in St. Maarten was recorded between midnight and 2 A.M. and in Statia between midnight and 1 A.M.

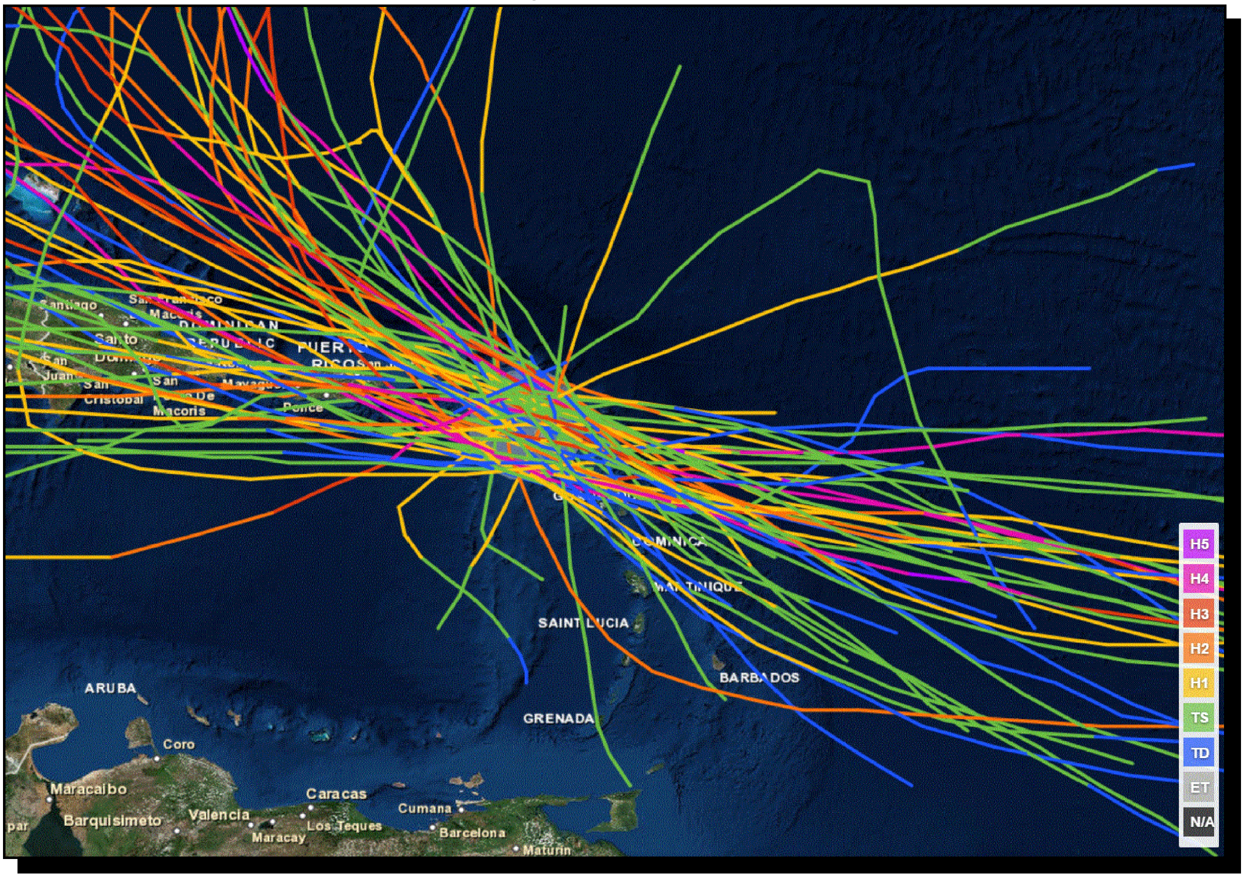
Hurricane Earl

Earl was a typical Cape Verde hurricane which was still intensifying as it passed just north of St. Maarten (about 40 kilometers) on August 30, 2010. It caused strong winds in these islands and there were periods with heavy rain. The material damage however was limited, mainly thanks to the fact that constructions have been built more hurricane resistant lately.



Number of tropical storms (green) and hurricanes (yellow) passing within 100 N.M. radius, in consecutive 10-day periods, 1881-1999

Tropical Cyclones Passing Within 60 Nautical Miles of Saba and St. Eustatius
(through December 31, 2013)



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Disaster Preparedness Organization in the Dutch Caribbean

The Meteorological Department Curaçao (MDC), a Government agency of Curaçao with its office and weather forecast center at Seru Mahuma is the authority responsible for the hurricane warning service. However, it is the responsibility of the Government of each country or island to maintain and activate a disaster preparedness organization.

Aside from the release of frequent public advisories, the MDC initiates, in case of meteorological emergencies, action in the following ways. Namely to the Governments through the Prime Ministers of Curaçao and the Lieutenant Governors of the BES Islands. The MDC will also contact the Islands' Disaster Coordinators of each country or island that is threatened.

Each island government has its own general disaster preparedness regulations. In principle the contents of these regulations are almost similar to each other, but aggravated to the different local circumstances, and call for the organization of a local disaster committee. An operational disaster plan is reviewed annually prior to the beginning of the hurricane season.

Further to the general government regulations there are so-called "Alarm orders" for the various public utility services and major industries (oil refineries and terminals, hotels, etc.). Copies of all these regulations and alarm orders are available at the National Meteorological Center for immediate special advice if conditions warrant.

In case of a disaster an island government may request assistance from the Dutch Caribbean for clean-up and rehabilitation, for example, additional manpower (police, the voluntary corps and the marines) and material or financial support through a special fund.

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Attachment I

Tropical Cyclones Passing Within 100 Nautical Miles of 12.5N 69.0W, Through December 31, 2014.

year	date	hour (AST)	minimum distance (nautical miles)	storm intensity	name	remarks
1605	-	-	-	ts	-	1)
1784	-	-	lt 25 S	hu	-	2)
1807	Oct. 17	night	lt 25	ts	-	3)
1831	June 24	0900	35 N	hu	-	4)
1876	Sep. 25	-	-	ts	-	5)
1877	Sep. 23	1130	lt 25 S	hu	-	6)
1886	Aug. 17	1800	lt 25 NNE	100 mph	-	7)
1887	July 21	1900	72 NE	100 mph	-	
1887	Dec. 9	1200	lt 25 NNW	60 mph	-	
1892	Oct. 7	2300	35 SSW	100 mph	-	8)
1895	Oct.17	0100	81 N	120 mph	-	
1897	Oct. 11	0400	72 N	50 mph	-	
1901	July 3	2000	50 N	50 mph	-	
1909	July 14	1900	91 NNE	40 mph	-	
1918	Aug. 2	1500	76 NNE	50 mph	-	
1918	Aug. 23	1700	67 NNE	80 mph	-	
1931	Sep. 7	---	99 NNE	ts	-	
1932	Nov. 2	0800	48 N	100 mph	-	
1933	June 29	0600	lt 25 NE	100 mph	-	
1933	Aug. 18	1600	92 NNE	40 mph	-	
1941	Sep. 25	0300	90 N	75 mph	-	
1954	Oct. 7	1300	50 N	120 mph	Hazel	9)
1955	Sep. 24	1400	81 NNW	80 mph	Janet	10)
1961	July 21	0100	38 NNW	70 mph	Anna	
1963	Oct. 1	2400	99 NNE	110 mph	Flora	
1969	Aug. 29	1900	36 N	30 mph	Francelia	
1971	Sep. 7	0800	lt 25 NNW	70 mph	Edith	
1971	Sep.16	0200	lt 25 S	35 mph	Irene	
1978	Aug.11	2000	40 N	35 mph	Cora	
1978	Sep. 14	1400	lt 25 N	45 mph	Greta	
1988	Oct. 16	1300	lt 25 S	50 mph	Joan	
1993	Aug. 8	0700	60 S	45 mph	Bret	
1996	Jul. 25	1700	lt 30 SW	45 mph	Cesar	
2004	Sep. 8	2300	65 N	145 mph	Ivan	
2005	Jul. 15	0300	100 NE	130 mph	Emily	
2007	Sep. 2	0700	30 N	105 mph	Felix	
2008	Oct. 14	1400	77 N	50 mph	Omar	
2010	Nov. 1	1300	56 N	45 mph	Tomás	

Remarks:

1. Based on the description of a disaster with a Spanish fleet near Cumaná, Venezuela. Ref. "Armada Española desde la unión de los reinos de Castilla y de Aragón", by Cesáres Fernandez Duro, Madrid, 1895, Vol.III, p. 487.

2. In the harbor of Willemstad, Curaçao, several full laden ships were swept ashore, others driven out to sea and lost. Other damages have been sustained to an immense value. A long range of warehouses was blown down and the goods buried under the ruins. Ref. "The Gentleman's Magazine", 1785, Vol. 57, p. 154.

3. In connection with the storm of June 24, 1831, reference is made to "the fatal night of October 17, 1807, when a hurricane past". No reports on damage available. Ref. "Curaçaosche Courant", June 1831.

4. Heavy storm and torrential rain with frequent thunder. Around 09:00 local time, the wind backed from NW to SW. No structural damage at Curaçao. HM brig "Sirene" lost at Kralendijk, Bonaire. Ref. "Curaçaosche Courant", June 1831. Known as the "Barbados-Yucatán hurricane".

5. Many houses of poor people were ruined, losses of live-stock in Aruba and Bonaire. Government buildings more or less damaged. Ref. "Colonial Report", 1877.

6. See text under "Hurricane climatology of the Dutch Caribbean - The Leeward islands". Ref. "Colonial Report", 1878.

7. Quays along harbor entrance heavily damaged, western part of Curaçao flooded, heavy trees were uprooted, stocks of salt were melted. In Bonaire, the Government pier was washed away and many ships lost, considerable damage to buildings and roads. At the north coast of Aruba, the German brig "Nero" was lost. Ref. "Colonial Report", 1887, "Curaçaosche Courant", August 20 and 27, 1886.

8. No damage reported in Curaçao, ship "Anita" lost near Bonaire. Strongest winds between 23:00 and 02:00 local time, lowest barometer reading 1013 mb (?). Ref. "Curaçaosche Courant", October 14, 1892.

9. Government pier in Bonaire damaged, flash floods in Curaçao and Aruba. In Aruba a bridge and several water dams destroyed. Wind speed about 30 knots with gusts to 50 knots. Ref. "Beurs- en Nieuwsberichten", October 7-14, 1954.

10. Some damage to quays along harbor entrance. Considerable damage to beach facilities at Piscadera Bay and Vaersen Bay. In Aruba, gusts to 50 mph, heavy trees uprooted but no significant damage. In Bonaire, piers and coastal boulevard damaged. Ref. "Beurs- en Nieuwsberichten" and "Amigoe di Curaçao" September 25, 1955

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Attachment II

Tropical Cyclones Passing Within 100 Nautical Miles of 17.5N 63.0W, through December 31, 2014.

year	date	hour (AST)	minimum distance (nautical miles)	storm intensity	name	remarks
1533	Oct.	-	-	hu	-	
1635	Aug.	-	100 SE	hu	-	
1642	Sep.	-	65 SE	hu+	-	
1650	-	-	lt 25 SE	hu	-	
1652	Sep.	-	lt 25 SW	hu	-	
1656	June	-	100 SE	hu	-	
1656	Aug.	-	100 SE	hu	-	
1657	Aug.	-	35 SW	hu	-	
1664	Oct.	-	70 SE	hu	-	
1666	Aug.	-	65 SE	hu+	-	
1667	Aug.	-	30 SE	hu	-	
1667	Sep.	-	lt 25 SE	hu+	-	
1681	Aug.	-	lt 25 SE	hu	-	
1681	Oct.	-	lt 25 SE	hu	-	
1684	Sep.	-	100 WNW	hu	-	
1691	-	-	75 ESE	hu	-	
1707	Sep.	-	lt 25 SE	hu+	-	
1713	Sep.	-	35 SW	hu	-	
1713	Oct.	-	30 N	hu	-	
1714	Aug.	-	100 SE	hu	-	
1718	Sep.	-	100 WNW	hu	-	
1718	Sep.	-	lt 25 SE	hu	-	
1728	Sep. 10	-	lt 25 SE	hu	-	
1733	July	-	lt 25 S	hu	-	
1737	Sep.	-	lt 25 SE	hu	-	
1738	Sep.	-	lt 25 SW	hu	-	
1740	Aug.	-	lt 25 SE	hu	-	
1742	Oct.	-	100 WNW	hu	-	
1758	Aug.	-	lt 25 SE	hu	-	
1760	Oct.	-	70 ENE	hu	-	
1765	July	-	lt 25 SE	hu	-	
1766	Sep. 14	-	lt 25 SE	hu	-	
1766	Oct. 7	-	lt 25 SE	hu	-	
1771	Aug.	-	lt 25 -	hu	-	
1772	Aug. 17	-	75 ESE	hu	-	
1772	Aug. 31	-	lt 25 WNW	hu+	-	1)
1772	Oct. 18	-	-	hu	-	
1772	Nov. 22	-	lt 25 SE	hu	-	
1773	July	-	100 WNW	hu	-	

1775	Oct. 16	-	lt 25 SE	hu	-	
1776	Sep. 5	-	lt 25 SW	hu	-	
1779	Sep. 5	-	lt 25 S	hu	-	
1780	Aug. 25	-	lt 25 SE	hu	-	
1780	Oct. 12	-	lt 25 -	hu+	-	2)
1785	July 25	-	100 WNW	hu	-	
1785	Aug. 25	-	lt 25 SE	hu	-	
1785	Aug. 31	-	100 SSW	hu	-	
1786	Aug. 11	-	lt 25 ENE	hu	-	3)
1790	Aug.	-	lt 25 SE	hu	-	
1792	July 14	-	lt 25 SE	hu	-	
1792	Aug. 2	0300	lt 25 NE	hu	-	4)
1792	Sep. 10	-	75 ESE	hu	-	
1793	Aug. 12	-	lt 25 -	hu	-	
1795	Aug. 18	-	75 ESE	hu	-	
1804	Sep. 3	-	lt 25 SE	hu+	-	
1806	Sep. 10	-	70 SW	hu+	-	
1807	July 26	-	50 SE	hu	-	
1809	July 27	-	100 SE	hu	-	
1809	Aug. 2	-	100 SE	hu	-	
1809	Sep. 2	-	lt 25 SW	hu	-	
1813	July 22	-	70 SW	hu	-	
1815	July 25	-	lt 25 SE	hu	-	
1815	Sep. 18	-	25 NNE	hu	-	
1816	Sep. 15	-	lt 25 SE	hu	-	
1817	Sep. 8	-	lt 25 SE	hu	-	
1818	Sep. 21	-	70 SW	hu	-	
1819	Sep. 21	-	60 SW	hu	-	
1820	Aug. 28	-	lt 25 SE	hu	-	
1821	Sep. 9	-	lt 25 NNE	hu	-	
1824	Sep. 7	-	100 SE	hu	-	
1825	July 26	-	lt 25 SW	hu	-	
1827	Aug. 17	-	lt 25 SW	hu+	-	
1829	Oct. 30	-	lt 25 SE	hu	-	
1830	Aug. 11	-	35 SW	hu	-	
1831	Aug. 11	-	80 SW	hu	-	
1833	Aug. 14	-	85 SE	hu	-	
1834	Sep. 20	-	75 SW	hu	-	
1835	Aug. 12	-	lt 25 NE	hu	-	
1837	July 31	-	lt 25 NE	hu	-	
1837	Aug. 2	-	lt 25 NE	hu	-	
1837	Aug. 12	-	100 N	hu	-	
1838	Nov. 13	-	lt 25 SE	hu	-	
1839	June 9	-	75 ESE	hu	-	
1846	Sep. 11	-	lt 25 S	hu	-	
1848	Aug. 22	-	lt 25 NE	hu	-	

1848	Sep. 19	-	lt 25 SE	hu	-	
1851	July 10	-	lt 25 SE	hu	-	
1851	Aug. 17	-	lt 25 N	hu	-	
1852	Sep. 22	-	lt 25 SE	hu	-	
1859	Sep. 2	-	lt 25 SE	hu	-	
1861	July 6	-	lt 25 SE	hu	-	
1867	Oct. 29	-	100 WNW	hu	-	
1871	Aug. 21	0800	lt 25 NE	hu	-	
1872	Sep. 10	1300	lt 25 E	hu	-	
1876	Sep. 12	2000	30 N	hu	-	5)
1878	Nov. 28	0400	lt 25 N	hu	-	
1879	Aug. 13	2200	50 N	hu	-	
1879	Sep. 11	0700	70 S	hu	-	
1880	Aug. 4	0400	90 S	hu	-	
1881	Aug. 21	2100	60 NNE	hu	-	
1888	Nov. 2	0800	96 E	60 mph	-	
1889	Sep. 3	0200	lt 25 NNE	100 mph	-	
1889	Oct. 2	0300	lt 25 WSW	60 mph	-	
1891	Aug. 19	0400	66 SW	100 mph	-	
1891	Oct. 2	0100	lt 25 N	50 mph	-	
1891	Oct. 13	1600	67 WSW	100 mph	-	
1893	Aug. 16	0300	41 SSW	120 mph	-	
1894	Oct. 13	0500	36 WSW	100 mph	-	
1896	Aug. 31	0400	97 SSW	120 mph	-	
1896	Sep. 22	0700	48 S	120 mph	-	
1898	Sep. 11	2200	lt 25 WSW	100 mph	-	6)
1898	Sep. 21	1000	lt 25 SSW	60 mph	-	
1898	Oct. 27	0800	lt 25 N	60 mph	-	
1899	Aug. 7	1800	39 SSW	100 mph	-	7)
1899	Aug. 30	1000	lt 25 NNE	80 mph	-	
1899	Sep. 8	1800	77 NNE	120 mph	-	8)
1900	Aug. 30	2200	lt 25 S	50 mph	-	
1901	Sep. 11	1200	49 N	50 mph	-	
1901	Oct. 8	2300	lt 25 S	35 mph	-	
1903	July 19	1100	31 SSW	30 mph	-	
1906	Sep. 2	0600	61 NNE	100 mph	-	
1908	Mar. 7	2300	lt 25 ESE	80 mph	-	
1908	Sep. 9	1800	67 NNE	60 mph	-	
1908	Sep. 25	1500	33 S	60 mph	-	
1909	Aug. 22	0500	lt 25 SSE	90 mph	-	
1910	Aug. 23	-	60 S	50 mph	-	
1910	Sep. 6	0200	lt 25 SSW	90 mph	-	
1915	Aug. 10	1800	lt 25 SSE	90 mph	-	
1916	July 12	1700	25 SW	40 mph	-	
1916	Aug. 21	1100	lt 25 N	100 mph	-	
1916	Aug. 29	0100	98 S	100 mph	-	

1916	Oct. 9	0900	67 WSW	75 mph	-
1917	Sep. 21	0600	88 SSW	80 mph	-
1922	Sep. 16	0500	34 NNE	115 mph	-
1923	Oct. 23	-	100 ENE	50 mph	-
1924	Aug. 18	0600	51 SW	40 mph	-
1924	Aug. 28	1300	lt 25 NNE	100 mph	-
1928	Sep. 12	1100	lt 25 SSW	130 mph	-
1930	Sep. 1	1800	64 SSW	100 mph	-
1931	Aug. 17	0100	81 SW	40 mph	-
1931	Sep. 10	0700	37 N	90 mph	-
1932	Aug. 30	-	95 NNE	40 mph	-
1932	Sep. 26	1100	39 N	120 mph	-
1933	July 14	0600	lt 25 SW	40 mph	-
1933	July 25	1500	33 NNE	50 mph	-
1933	Aug. 29	0100	96 N	50 mph	-
1933	Sep. 27	1700	lt 25 N	40 mph	-
1934	Aug. 21	-	100 S	50 mph	-
1934	Sep. 18	0100	59 NE	50 mph	-
1937	Aug. 24	1200	85 NNE	40 mph	-
1938	Aug. 8	0400	lt 25 NNE	65 mph	-
1939	Aug. 7	0600	79 N	30 mph	-
1939	Oct. 12	0600	88 NNE	30 mph	-
1940	Aug. 5	0600	72 NNW	50 mph	-
1942	Nov. 4	0800	53 SSW	30 mph	-
1943	Aug. 13	1700	30 NE	40 mph	-
1945	Aug. 3	0100	84 SSW	55 mph	-
1947	Oct. 16	1300	25 NNE	40 mph	-
1949	Aug. 23	1000	62 NNE	60 mph	-
1949	Sep. 20	-	90 S	50 mph	-
1950	Aug. 22	1200	43 S	70 mph	Baker
1950	Sep. 1	1300	46 NNE	120 mph	Dog (see text)
1953	Sep. 14	1000	lt 25 NE	40 mph	Edna
1954	Sep. 4	0200	97 NE	40 mph	Edna
1955	Sep. 10	2400	53 NE	40 mph	Hilda
1956	Aug. 11	1900	60 SSW	90 mph	Betsy
1958	Aug. 30	1600	95 SSW	40 mph	Ella
1959	July 18	1400	32 SSW	50 mph	Edith
1960	Sep. 4	2300	36 NNE	145 mph	Donna (see text)
1961	Oct. 1	1200	88 S	40 mph	Frances
1961	Nov. 1	0600	65 ESE	30 mph	Inga
1962	Oct. 1	0900	95 ENE	40 mph	Daisy
1963	Oct. 27	1500	70 SE	50 mph	Helena
1964	Aug. 22	1700	81 S	100 mph	CEO
1965	Aug. 28	2300	lt 25 E	55 mph	Betsy
1966	Aug. 26	0700	63 NNE	90 mph	Faith
1966	Sep. 27	1900	72 S	130 mph	Inez

1971	Aug. 23	0800	lt 25 NNE	30 mph	Doria
1973	Sep. 3	2000	lt 25 ESE	45 mph	Christine
1974	Aug. 29	1900	53 S	35 mph	Carmen
1975	Sep. 14	-	50 N	35 mph	Eloise (see text)
1979	July 17	1600	lt 25 NNE	45 mph	Claudette
1979	Aug. 29	2200	99 SSW	150 mph	David
1979	Sep. 3	1600	lt 25 NNE	75 mph	Frederic (see text)
1981	Sep. 4	1300	lt 25 NNW	30 mph	Floyd
1984	Nov. 8	0200	87 N	75 mph	Klaus
1989	Aug. 3	0600	65 NNE	85 mph	Dean
1989	Sep. 17	1300	38 SSW	140 mph	Hugo (see text)
1990	Oct. 6	2200	70 N	70 mph	Klaus
1995	Aug. 27	2000	60 E	65 mph	Iris
1995	Sep. 5	2000	30 NE	145 mph	Luis (see text)
1995	Sep.15	1100	62 SW	95 mph	Marilyn (see text)
1996	Jul. 8	0500	lt 40 SE	80 mph	Bertha
1998	Aug. 21	2300	75 NE	50 mph	Bonnie
1998	Sep. 21	0500	45 S	100 mph	Georges (see text)
1999	Oct. 20	1700	lt 15 S	75 mph	José (see text)
1999	Nov. 18	1700	lt 1 W	115 mph	Lenny (see text)
2000	Aug. 22	0600	lt 1 W	75 mph	Debby
2006	Aug. 2	0400	77 NE	60 mph	Chris
2008	Oct. 16	0300	72 NW	120 mph	Omar
2010	Aug. 30	0600	54 NE	115 mph	Earl (see text)
2011	Aug. 21	1100	25 S	50 mph	Irene
2011	Sep. 10	1800	42 NE	50 mph	Maria
2012	Oct. 13	1800	26 W	50 mph	Rafael
2014	Oct. 13	1800	21 NE	85 mph	Gonzalo

Remarks:

1. In St. Maarten only a few houses remained and all plantations were destroyed..... In St. Eustatius 400 houses on higher grounds were destroyed or damaged beyond repair, all land houses were blown away.....(Southey).

2. In St. Eustatius very heavy damage. Seven ships ran ashore near North Point and their crew drowned. An estimated 4000-5000 persons lost their lives in St. Eustatius.

3. In St. Eustatius all ships were driven out to sea and small crafts in the harbor were destroyed.

4. Hurricane vortex at 4 a.m. over St. Barthelemey, later over Anguilla and Sombrero .... most of the other islands also suffered .... (Southey).

5. So called "San Felipe hurricane" (1st). Considerable damage, mainly in St. Maarten and Saba. No lives were lost. Ref. "Colonial Report", 1877.

6. Many ships and fishing boats were lost. In Saba and St. Maarten, many houses were destroyed and some older buildings more or less damaged. The potato crop at Saba was completely lost. Ref. "Colonial Report", 1899.

7. In St. Eustatius, 50 houses were destroyed and about 150 others heavily damaged. Only one live was lost. Saba experienced torrential rains destroying most of the crop and also damage to roads. Almost no damage at St. Maarten. Ref. "Colonial Report", 1900. Known as "San Ciriaco hurricane".

8. In St. Maarten, more than 100 houses were destroyed and two persons lost their lives. Particularly agriculture experienced heavy losses and also the fishermen lost all their equipment. In Saba, the remainder of the crop was lost. Not much damage In St. Eustatius. Ref. "Colonial Report", 1900.

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Attachment III

International Hurricane Scale (IHS)

The scale to be used for international classification of hurricanes is as follows:

IHS Number Corresponding Wind Speed (V_n)

n	m/s	km/h	knots	m.
1.0	33	118	64	73
1.5	40	144	78	90
2.0	46	166	90	10
2.5	52	186	100	11
3.0	57	204	110	12
3.5	61	220	119	13
4.0	65	235	127	14
4.5	69	250	135	15
5.0	73	263	142	16
5.5	77	276	149	17
6.0	80	288	156	17
6.5	83	300	162	18
7.0	87	311	168	19
7.5	90	322	174	20
8.0	92	333	180	20
8.5	95	343	185	21
9.0	98	353	191	21
9.5	101	363	196	22
10.0	103	372	201	23

The wind speed corresponding to IHS numbers greater than 10 may be derived from the following relationships:

m/s: $V_n = 32.7n$ knots: $V_n = 63.563568n$
km/h: $V_n = 117.72n$ m.p.h.: $V_n = 73.147938n$

where V_n represents a hurricane with n times the kinetic energy per unit mass of the threshold hurricane (V1).

NOTE: 100 km/h = 62 m.p.h. = 54 knots = 28 m/s.

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Attachment IV

Hurricane Intensity Scale in Use by the U.S.A.

A 'scale'* from one to five based on the hurricane's present intensity which gives an estimate of the potential property damage and flooding along the coast from a hurricane is as follows:

One:	Winds 119-153 km/h (74-95 mph). Very dangerous winds will produce some damage. People, livestock, and pets struck by flying or falling debris could be injured or killed. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal road flooding and minor pier damage.
Two:	Winds 155-177 km/h (96-110 mph) or storm surge 1.8 - 2.4 m (6-8 feet) above normal- Some roofing material, door, and window damage to buildings. Considerable damage to vegetation, exposed mobile homes, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of center. Small craft in unprotected anchorages break moorings.
Three:	Winds 179-193 km/h (111-130 mph) or storm surge 2.7 - 3.7 m (9-12 feet) above normal - Some structural damage to small residences and utility buildings with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures and larger structures damaged by floating debris. Terrain continuously lower than 1.5 m (5 feet) may be flooded inland 13 km (8 miles) or more.
Four:	Winds 195-233 km/h (131-155 mph) or storm surge 4 - 5.5 m (13-18 feet) above normal - More extensive curtain wall failures with some complete roof structure failure on small residences. Major damage to lower floors of structures near the shore. Terrain flooded inland as far as 9.7 km (5 miles).
Five:	Winds greater than 233 km/h (155 mph) or storm surge greater than 5.5 m (18 feet) above normal - Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Major damage to lower floors of all structures located less than 4.6 m (15 feet) above sea-level and within 460 m (500 yards) of the shoreline.

* This scale was developed by **Saffir and Simpson** and is commonly known as the Saffir/Simpson Hurricane Scale (SSH).

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Attachment V

Words of Warning:

GALE WARNING: When winds of 38-55 miles per hour (33-48 knots) are expected, a gale warning is added to the advisory message.

STORM WARNING: When winds of 55-74 miles per hour (48-64 knots) are expected, a storm warning is added to the advisory message.
When gale or storm warnings are part of a tropical cyclone advisory, they may change to a hurricane warning if the storm continues along the coast.

HURRICANE WATCH: If the hurricane continues its advance and threatens coastal and inland regions, a hurricane watch is added to the advisory, covering a specified area and duration. A hurricane watch means that hurricane conditions are a real possibility within 48 hours; it does not mean they are imminent. When a hurricane watch is issued, everyone in the area covered by the watch should listen for further advisories and be prepared to act quickly if hurricane warnings are issued.

HURRICANE WARNING: When hurricane conditions are expected within 36 hours, a hurricane warning is added to the advisory. Hurricane warnings identify coastal areas where winds of at least 74 miles per hour are expected to occur. A warning may also describe coastal areas where dangerously high water or exceptionally high waves are forecast, even though winds may be less than hurricane force.

When the hurricane warning is issued, all precautions should be taken immediately. Hurricane warnings are seldom issued more than 36 hours in advance. If the hurricane's path is unusual or erratic, the warnings may be issued only a few hours before the beginning of hurricane conditions.

Tornadoes spawned by hurricanes are among the storms' worst killers. When a hurricane approaches, listen for tornado watches and warnings. A tornado watch means tornadoes are expected to develop. A tornado warning means a tornado has actually been sighted. When your area receives a tornado warning, seek inside shelter immediately.

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