

= Tropical cyclone observation =

Tropical cyclone observation has been carried out over the past couple of centuries in various ways . The passage of typhoons , hurricanes , as well as other tropical cyclones have been detected by word of mouth from sailors recently coming to port or by radio transmissions from ships at sea , from sediment deposits in near shore estuaries , to the wiping out of cities near the coastline . Since World War II , advances in technology have included using planes to survey the ocean basins , satellites to monitor the world 's oceans from outer space using a variety of methods , radars to monitor their progress near the coastline , and recently the introduction of unmanned aerial vehicles to penetrate storms . Recent studies have concentrated on studying hurricane impacts lying within rocks or near shore lake sediments , which are branches of a new field known as paleotempestology . This article details the various methods employed in the creation of the hurricane database , as well as reconstructions necessary for reanalysis of past storms used in projects such as the Atlantic hurricane reanalysis .

= = Geological markers of past activity = =

= = = Stalagmites in caves = = =

Recent studies of the ^{18}O and ^{13}C isotopes found in stalagmites in Belize show that tropical cyclone events can leave markers that can be separated out on a week @-@ by @-@ week basis . The error rate of this type of microanalysis was 1 error in 1 @,@ 200 sampling points .

= = = Markers in coral = = =

Rocks contain certain isotopes of elements , known as natural tracers , which describe the conditions under which they formed . By studying the calcium carbonate in coral rock , past sea surface temperature and hurricane information can be revealed . Lighter oxygen isotopes (^{18}O) are left behind in coral during periods of very heavy rainfall . Since hurricanes are the main source of extreme rainfall in the tropical oceans , past hurricane events can be dated to the days of their impact on the coral by looking at the increased ^{18}O concentration within the coral .

= = = Sediment deposition in coastal lakes = = =

Kam Biu @-@ Liu , a professor at Louisiana State University , has been studying sediment lying at the bottom of coastal lakes and marshes in order to study the frequency and intensity of hurricanes over the past 5 @,@ 000 years . Since storm surges sweep coastal sands with them as they progress inland , a layer of sand is left behind in coastal lakes and marshes . Radiocarbon dating is then used to date the layers .

= = Newspapers = =

Before the invention of the telegraph in the early to mid @-@ 19th century , news was as fast as the quickest horse , stage , or ship . Normally , there was no advance warning of a tropical cyclone impact . However , the situation changed in the 19th century as seafaring people and land @-@ based researchers , such as Father Viñes in Cuba , came up with systematic methods of reading the sky 's appearance or the sea state , which could foretell a tropical cyclone 's approach up to a couple days in advance .

In China , the abundance of historical documentary records in the form of Fang Zhi (semiofficial local gazettes) offers an extraordinary opportunity for providing a high @-@ resolution historical dataset for the frequency of typhoon strikes . Kam @-@ biu Liu et al . (2001) reconstructed a 1 @,@ 000 @-@ year time series of typhoon landfalls in the Guangdong Province of southern China

since AD 975 and found that on a decadal timescale , the twenty @-@ year interval from AD 1660 to 1680 is the most active period on record , with twenty @-@ eight to thirty @-@ seven typhoon landfalls per decade . The variability in typhoon landfalls in Guangdong mimics that observed in other paleoclimatic proxies (e.g. , tree rings , ice cores) from China and the northern hemisphere . Remarkably , the two periods of most frequent typhoon strikes in Guangdong (AD 1660 @-@ 1680 , 1850 ? 1880) coincide with two of the coldest and driest periods in northern and central China during the Little Ice Age .

= = Surface observations = =

= = = Ship reports = = =

For centuries , people have sailed the world 's oceans and seas , and for just as long , they have encountered storms . The worst of the cyclones over the open seas likely took those that observed them into the depths of the oceans . However , some did survive to report harrowing tales . Before the invention of the wireless telegraph in 1905 , reports about storms at sea either coincided with their arrival at the coast as ships scrambled into port , or came weeks and months afterwards from remote ports of call . Ship and buoy reports , available since the 1970s , are used in real @-@ time not only for their temperature , pressure , and wind measurements , but also for their sea surface temperature and wave height measurements .

Wind reports from ships at sea have become increasingly based on anemometers , and less so on the Beaufort Scale . This is important to note as the Beaufort Scale underestimates winds at higher wind speeds , indicating ship wind observations taken for older storms are likely to underrepresent their true value .

As Christopher Landsea et al. point out , many tropical cyclones that formed on the open sea and did not affect any coast usually went undetected prior to satellite observation since the 1970s . They estimated an undercount bias of zero to six tropical cyclones per year between 1851 and 1885 and zero to four per year between 1886 and 1910 . These undercounts roughly take into account the typical size of tropical cyclones , the density of shipping tracks over the Atlantic basin , and the amount of populated coastline .

= = = Land @-@ based observations = = =

In the early 20th century , forecasting the track of cyclones was still confined to areas of the greatest surface pressure falls , based upon surface weather observations , and climatology . These methods proved to be the cutting edge of tropical cyclone forecasting through the mid 20th century . Land @-@ based surface observations remain invaluable as a source of real @-@ time information at locations near the coastline and inland . Combined with ship observations and newspapers , they formed the total information network for hurricane detection until radiosondes were introduced in 1941 and reconnaissance aircraft began in 1944 . Land @-@ based observations of pressure and wind can show how quickly a tropical cyclone is decaying as it moves inland . Their rainfall reports show where significant rainfall is occurring , and can be an alert for possible flooding . With the establishment of the ASOS network in the United States during the 1990s , more locations are reporting around the clock than ever before .

= = = = Mobile platforms = = = =

Since the 1990s , academic researchers have begun to deploy mobile weather stations fortified to withstand hurricane @-@ force winds . The two largest programs are the Florida Coastal Monitoring Program and the Wind Engineering Mobile Instrumented Tower Experiment . During landfall , the NOAA Hurricane Research Division compares and verifies data from reconnaissance aircraft , including wind speed data taken at flight level and from GPS dropwindsondes and stepped @-@

frequency microwave radiometers , to wind speed data transmitted in real time from weather stations erected near or at the coast . The National Hurricane Center uses the data to evaluate conditions at landfall and to verify forecasts .

= = Upper air observations = =

= = = Reconnaissance aircraft = = =

The idea of aircraft reconnaissance of tropical cyclones first was put forth by Captain W. L. Farnsworth of the Galveston Commercial Association in the early 1930s . Supported by the United States Weather Bureau , it passed both the United States Senate and United States House of Representatives in 1936 . Since 1944 , aircraft have been flying out to sea to find tropical cyclones . Before regular satellite coverage , this was a hit @-@ or @-@ miss affair . Thereafter , aircraft flights into tropical systems became more targeted and precise . Nowadays , a C @-@ 130 is used as a hurricane hunter by the Air Force , while the P @-@ 3 Orion is used by the National Oceanic and Atmospheric Administration for research projects used to better understand tropical cyclones and improve hurricane forecasts . The implementation of synoptic observation missions by a Gulfstream jet , where dropwindsondes are used to investigate a tropical cyclone 's environment , has led to a 15 @-@ 20 percent reduction in track forecast errors where such missions were present .

Historical aircraft used for weather and hurricane tracking include :

RK @-@ 47 USAF

WB @-@ 29 USAF

WB @-@ 57F - NASA

B @-@ 50 USAF

WB @-@ 50D USAF

WC @-@ 135B USAF

WC @-@ 130 USAF

In Canada , the Convair 580 is used by National Research Council to track hurricanes .

= = = Unmanned aerial vehicles = = =

The era of the aerosonde began in 1998 , when the Australian Bureau of Meteorology flew an aerosonde into Tropical Cyclone Tiffany . In 2005 , Hurricane Ophelia became the first Atlantic tropical cyclone where an unmanned aerial vehicle , known as an aerosonde , mission was used for a tropical cyclone . The first typhoon was penetrated by an aerosonde in 2005 as well . Unlike normal reconnaissance flights , the aerosonde stayed near the surface after a 10 @-@ hour flight within the tropical cyclone .

= = Remote sensing = =

= = = Radar = = =

During World War II , radar technology was developed to detect aircraft . It soon became apparent that large areas became obscured when significant weather was in the area . In 1957 , the National Weather Service established the United States ' first radar network to cover the coastline and act as first warning of an impending tropical cyclone . Upgraded in the 1990s to use doppler technology , radar can provide rainfall estimates , wind estimates , possible locations of tornadoes within a system 's spiral bands , as well as the center location of a tropical cyclone . The United States operates with a network of 158 Doppler Radars across the country .

=== Satellite ===

Beginning with the launching of TIROS @-@ I in April 1960 , satellites have been used to look for tropical cyclones . The Dvorak technique was developed from early satellite images of tropical cyclones to determine real @-@ time a tropical cyclone 's strength from characteristics seen on satellite imagery . In most tropical cyclone basins , use of the satellite @-@ based Dvorak technique is the primary method used to determine a tropical cyclone 's maximum sustained winds . The extent of banding and difference in temperature between the eye and eyewall is used within the technique to assign a maximum sustained wind and pressure . Since the mid @-@ 1990s , microwave imagery has been able to determine the center of rotation when that center is obscured by mid to high level cloudiness . Cloud top temperatures are used in real @-@ time to estimate rainfall rates within the cyclone .