= Tropical cyclone track forecasting =

Tropical cyclone track forecasting involves predicting where a tropical cyclone is going to track over the next five days , every 6 to 12 hours . The history of tropical cyclone track forecasting has evolved from a single station approach to a comprehensive approach which uses a variety of meteorological tools and methods to make predictions . The weather of a particular location can show signs of the approaching tropical cyclone , such as increasing swell , increasing cloudiness , falling barometric pressure , increasing tides , squalls , and heavy rainfall .

The forces that affect tropical cyclone steering are the higher latitude westerlies , the subtropical ridge , and the beta effect caused by changes of the coriolis force within fluids such as the atmosphere . Accurate track predictions depend on determining the position and strength of high and low pressure areas , and predicting how those areas will migrate during the life of a tropical system . Computer forecast models are used to help determine this motion as far out as five to seven days in the future .

= = History = =

The methods through which tropical cyclones are forecast have changed with the passage of time . The first known forecasts in the Western Hemisphere were made by Lt. Col. William Reed of the Corps of Royal Engineers at Barbados in 1847 . Reed mostly utilized barometric pressure measurements as the basis of his forecasts . Benito Viñes , S.J. , introduced a forecast and warning system based on cloud cover changes in Havana during the 1870s . Forecasting hurricane motion was based on tide movements , as well as cloud and barometer changes over time . In 1895 , it was noted that cool conditions with unusually high pressure preceded tropical cyclones in the West Indies by several days . Before the early 1900s , most forecasts were done by direct observations at weather stations , which were then relayed to forecast centers via telegraph . It was not until the advent of radio in the early twentieth century that observations from ships at sea were available to forecasters . Despite the issuance of hurricane watches and warnings for systems threatening the coast , forecasting the path of tropical cyclones did not occur until 1920 . By 1922 , it was known that the winds at 3 kilometres ( 9 @,@ 800 ft ) to 4 kilometres ( 13 @,@ 000 ft ) in height above the sea surface within the storms ' right front quadrant were representative of a storm 's steering , and that hurricanes tended to follow the outermost closed isobar of the subtropical ridge .

In 1937 , radiosondes were used to aide tropical cyclone forecasting . The next decade saw the advent of aircraft @-@ based reconnaissance by the military , starting with the first dedicated flight into a hurricane in 1943 , and the establishment of the Hurricane Hunters in 1944 . In the 1950s , coastal weather radars began to be used in the United States , and research reconnaissance flights by the precursor of the Hurricane Research Division began in 1954 . The launch of the first weather satellite , TIROS @-@ I , in 1960 , introduced new techniques to tropical cyclone forecasting that remain important to the present day . In the 1970s , buoys were introduced to improve the resolution of surface measurements , which until that point , were not available at all over sea surfaces .

= = Single station forecasting of a tropical cyclone passage = =

About four days in advance of a typical tropical cyclone , an ocean of 1 metre ( 3 @.@ 3 ft ) in height will roll in about every 10 seconds , moving towards the coast from the direction of the tropical cyclone 's location . The ocean swell will slowly increase in height and frequency the closer a tropical cyclone gets to land . Two days in advance of the center 's passage , winds go calm as the tropical cyclone interrupts the environmental wind flow . Within 36 hours of the center passage , the pressure begins to fall and a veil of white cirrus clouds approaches from the cyclone 's direction . Within 24 hours of the closest approach to the center , low clouds begin to move in , also known as the bar of a tropical cyclone , as the barometric pressure begins to fall more rapidly and the winds begin to increase . Within 18 hours of the center 's approach , squally weather is common , with sudden increases in wind accompanied by rain showers or thunderstorms . Winds increase within

12 hours of the center 's approach , occasionally reaching hurricane force . The ocean 's surface becomes whipped with foam . Small items begin flying in the wind . Within 6 hours of the center 's arrival , rain becomes continuous and the storm surge begins to come inland . Within an hour of the center , the rain becomes very heavy and the highest winds within the tropical cyclone are experienced . When the center arrives with a strong tropical cyclone , weather conditions improve and the sun becomes visible as the eye moves overhead . At this point , the pressure ceases to drop as the lowest pressure within the storm 's center is reached . This is also when the peak depth of the storm surge occurs . Once the system departs , winds reverse and , along with the rain , suddenly increase . The storm surge retreats as the pressure suddenly rises in the wake of its center . One day after the center 's passage , the low overcast is replaced with a higher overcast , and the rain becomes intermittent . By 36 hours after the center 's passage , the high overcast breaks and the pressure begins to level off .

= = Basics = =

The large scale synoptic scale flow determines 70 to 90 percent of a tropical cyclone 's motion . The deep @-@ layered mean flow through the troposphere is considered to be the best tool in determining track direction and speed . If storms experience significant vertical wind shear , use of a lower level wind such as the 700 hPa pressure level ( at a height of 3 @,@ 000 metres ( 9 @,@ 800 ft ) above sea level ) will work out as a better predictor . Knowledge of the beta effect can be used to steer a tropical cyclone , since it leads to a more northwest heading for tropical cyclones in the Northern Hemisphere due to differences in the coriolis force around the cyclone . For example , the beta effect will allow a tropical cyclone to track poleward and slightly to the right of the deep layer steering flow while the system lies the south of the subtropical ridge . Northwest moving storms move quicker and left , while northeast moving storms move slower and left . The larger the cyclone , the larger the impact of the beta effect is likely to be .

= = = Fujiwhara effect = = =

When two or more tropical cyclones are in proximity to one another , they begin to rotate cyclonically around the midpoint between their circulation centers . In the northern hemisphere , this is in a counterclockwise direction , and in the southern hemisphere , a clockwise direction . Usually , the tropical cyclones need to be within 1 @,@ 450 kilometres ( 900 mi ) of each other for this effect to take place . It is a more common phenomenon in the northern Pacific ocean than elsewhere , due to the higher frequency of tropical cyclone activity which occurs in that region .

= = = Trochoidal motions = = =

Small wobbles in a tropical cyclone 's track can occur when the convection is distributed unevenly within its circulation . This can be due to changes in vertical wind shear or inner core structure . Because of this effect , forecasters use a longer term ( 6 to 24 hours ) motion to help forecast tropical cyclones , which acts to smooth out such wobbles .

= = Forecast models = =

High @-@ speed computers and sophisticated simulation software allow meteorologists to run computer models that forecast tropical cyclone tracks based on the future position and strength of high- and low @-@ pressure systems . Combining forecast models with increased understanding of the forces that act on tropical cyclones , and a wealth of data from Earth @-@ orbiting satellites and other sensors , scientists have increased the accuracy of track forecasts over recent decades . The addition of dropwindsonde missions around tropical cyclones in what are known as synoptic flow missions in the Atlantic Basin decreased track error by 15 @-@ 20 percent . Using a consensus of forecast models , as well as ensemble members of the various models , can help reduce forecast

error . However , regardless how small the average error becomes , large errors within the guidance are still possible . An accurate track forecast is important , because if the track forecast is incorrect , forecasts for intensity , rainfall , storm surge , and tornado threat will also be incorrect .

= = Length of forecast period = =

Forecasts within hurricane advisories were issued one day into the future in 1954 before being extended to two days into the future in 1961 , and three days into the future in 1964 . Starting in the mid to late 1990s , research into tropical cyclones and how forecast models handle the systems led to substantial improvements in track error . By 2001 , the error had reduced sufficiently to extend track out to 5 days in the future on public advisories . In addition , at 1700 UTC during the hurricane season , a medium range coordination call takes place between the Hydrometeorological Prediction Center and the National Hurricane Center to coordinate tropical cyclone placement on the medium range pressure forecasts 6 and 7 days into the future for the northeast Pacific and Atlantic basins . Every so often , even at this time range , successful predictions can be made .

In forecasts , the National Hurricane Center uses a track forecast cone for the graphical representation of the uncertainty in its forecasts of a tropical cyclone 's future location . The cone represents the probable position of a tropical cyclone 's circulation center , and is made by drawing a set of circles centered at each forecast point ? 12 , 24 , 36 , 48 , and 72 hours for a three @-@ day forecast , as well as 96 and 120 hours for a five @-@ day forecast . The radius of each circle is equal to encompass two @-@ thirds of the historical official forecast errors for the preceding five @-@ year period . The cone is then constructed by drawing a tangent line that connects the outside boundary of all the circles . The National Hurricane Center states that the entire track of the tropical cyclone " can be expected to remain within the cone roughly 60 @-@ 70 % of the time . "