

= Meteorological history of Hurricane Ivan =

The meteorological history of Hurricane Ivan , the longest tracked tropical cyclone of the 2004 Atlantic hurricane season , lasted from late August through late September . The hurricane developed from a tropical wave that moved off the coast of Africa on August 31 . Tracking westward due to a ridge , favorable conditions allowed it to develop into Tropical Depression Nine on September 2 in the deep tropical Atlantic Ocean . The cyclone gradually intensified until September 5 , when it underwent rapid deepening and reached Category 4 status on the Saffir @-@ Simpson Hurricane Scale ; at the time Ivan was the southernmost major North Atlantic hurricane on record .

Ivan quickly weakened due to dry air , but it gradually reorganized , passing just south of Grenada as a major hurricane on September 7 . The hurricane attained Category 5 status in the central Caribbean Sea . Over the subsequent days its intensity fluctuated largely due to eyewall replacement cycles , and Ivan passed just south of Jamaica , the Cayman Islands , and western Cuba with winds at or slightly below Category 5 status . Turning northward and encountering unfavorable conditions , Ivan gradually weakened before making landfall just west of Gulf Shores , Alabama on September 16 with winds of 120 mph ( 195 km / h ) . The cyclone quickly weakened to tropical depression status as it turned to the northeast , and Ivan transitioned into an extratropical cyclone on September 18 .

The remnant low of Ivan turned to the south and southwest , and after crossing Florida on September 21 it began to reacquire tropical characteristics . It became a tropical depression again on September 22 to the southeast of Louisiana , and Ivan reached winds of 60 mph ( 95 km / h ) before weakening and moving ashore along southwestern Louisiana as a tropical depression ; the circulation of Ivan dissipated after crossing into Texas on September 25 . The cyclone broke several intensity records , and its duration was the tenth longest on record for an Atlantic hurricane .

= = Formation and intensification = =

On August 31 , a large tropical wave moved off the west coast of Africa . A tropical system along the wave axis contained a low pressure area as well as an impressive outflow pattern , though initially its convection was disorganized and limited . By September 1 a cyclonic circulation with a diameter of 690 mile ( 1115 km ) was evident on satellite imagery , well to the southeast of the Cape Verde Islands , and several hurricane forecast models anticipated development and strengthening . As it tracked quickly westward , the convection organized and developed into rainbands ? bands of showers and thunderstorms that spiral cyclonically toward the storm center ? and late on September 1 meteorologists began tracking the system using the Dvorak technique . Low amounts of wind shear and favorable outflow allowed vigorous deep convection to develop and persist near the center , and by 1800 UTC on September 2 the system developed into Tropical Depression Nine about 450 miles ( 730 km ) southwest of Praia , Cape Verde .

Upon being classified as a tropical cyclone , the depression was embedded within a deep easterly steering current provided by a ridge to its north . Expected to track across sea surface temperatures greater than 82 ° F ( 28 ° C ) , the cyclone was forecast to gradually strengthen and within four days attain hurricane status ; the Geophysical Fluid Dynamics Laboratory predicted the depression to reach Category 4 status on the Saffir @-@ Simpson Hurricane Scale within three days . Increased northeasterly wind shear shifted the center to the northeastern edge of the deep convection , and despite the shear and its relatively low latitude of 9 @.@ 7 ° N , the depression strengthened to attain tropical storm status early on September 3 ; upon reaching the intensity , the National Hurricane Center classified the system as Tropical Storm Ivan .

Tropical Storm Ivan gradually became better organized as wind shear decreased , and its outflow expanded in all quadrants . Satellite imagery late on September 3 depicted a well @-@ defined curved band wrapping around much of the circulation . The next day , the deep convection temporarily became ill @-@ defined , before reorganizing and developing an eye feature . Convection strengthened further as the feature transitioned into an eye , and Ivan became a hurricane at around 0600 UTC on September 5 . After reaching hurricane status , Ivan began to

rapidly intensify with continued favorable conditions , and in an 18 ? hour period the pressure dropped 39 mbar ( 1 @.@ 15 inHg ) as the winds increased by 60 mph ( 95 km / h ) ; early on September 6 Ivan attained an initial peak intensity of 135 mph ( 215 km / h ) while located about 825 miles ( 1330 km ) east of the island of Tobago in the southern Lesser Antilles .

While at major hurricane status , Ivan maintained very strong convection in its core with a well @-@ defined eye . Operationally , the probability for further rapid strengthening was considered nearly nine times the average of a typical hurricane . Accordingly , Ivan was forecast to pass near Barbados with winds of about 150 mph ( 240 km / h ) . Shortly after attaining Category 4 status , the outer convection of the hurricane became ragged . Hurricane Hunters found a Saharan Air Layer in the northern portion of the eye , leaving the eyewall eroded which caused a marked decrease in winds ; by late on September 6 Ivan weakened to winds of 105 mph ( 165 km / h ) . The inner eyewall dissipated as a 23 mile ( 37 km ) outer eyewall became dominant , and concurrently the overall organization of the hurricane improved . Ivan again attained major hurricane status as it approached the Lesser Antilles , and at 2130 UTC on September 7 the cyclone passed 7 miles ( 11 km ) south @-@ southwest of the southern tip of Grenada , its closest approach to the island . At the time , the hurricane maintained an eye diameter of 12 miles ( 19 km ) , with the northern portion of the eyewall producing strong winds on the island . The hurricane brought strong winds to Grenada , and tropical storm force winds were reported as far north as Dominica .

= = Caribbean Sea = =

Hurricane Ivan again reached Category 4 status as it entered the Caribbean Sea . Subsequently , it underwent an eyewall replacement cycle , and for about 18 hours the intensity remained constant as it paralleled the northern coast of Venezuela offshore . Another period of rapid deepening began late on September 8 as its motion turned to the west @-@ northwest . Hurricane Hunters recorded flight @-@ level sustained winds of 180 mph ( 290 km / h ) to the north and northeast of the eye , and a dropsonde about 630 feet ( 190 m ) above the surface recorded winds of 200 mph ( 325 km / h ) and an extrapolated pressure of 916 mbar ( 27 @.@ 05 inHg ) . Based on the reports , it is estimated Ivan attained Category 5 status at 0600 UTC on September 9 , while located about 90 miles ( 145 km ) north of Aruba . At the time , the cyclone was forecast to strike southern Florida as a major hurricane .

After maintaining Category 5 status for about 12 hours , Ivan began a steady weakening trend due to another eyewall replacement cycle until reaching winds of 140 mph ( 225 km / h ) on September 10 . Early next day , the hurricane reorganized as it reached winds just shy of Category 5 status . However , weakening occurred again due to an eyewall replacement cycle , and at 0330 UTC on September 11 Ivan passed 23 miles ( 37 km ) south of Portland Point , Jamaica , its closest approach , with winds of 150 mph ( 240 km / h ) . The hurricane was previously forecast to make landfall on the island , though the weakening and a turn to the west kept the strongest winds offshore ; however , sustained winds of Category 4 status were reported . While passing to the south of the island , the hurricane dropped heavy rainfall , with several stations reporting over 2 feet ( 60 cm ) of precipitation . Ivan 's last @-@ minute turn to the west was due to a mid @-@ level high pressure system over the eastern Gulf of Mexico . A slight weakening trend continued after passing the island , due to its northern outflow being disrupted by an upper @-@ level low over the Bahamas . As it tracked further away from Jamaica , Ivan again rapidly intensified to Category 5 status , and early on September 12 it reached its peak intensity of 165 mph ( 265 km / h ) with a pressure of 910 mbar ( 26 @.@ 87 inHg ) .

Shortly after peaking in intensity , the hurricane again weakened as it underwent an eyewall replacement cycle . At 1415 UTC on September 12 Ivan passed 25 miles ( 40 km ) south @-@ southwest of George Town , Cayman Islands , with sustained winds of 150 mph ( 240 km / h ) were reported . The storm surge from the hurricane flooded all of Grand Cayman Island . After its eyewall became re @-@ established Ivan attained Category 5 status for a third time early on September 13 . Shortly thereafter , a trough created a weakness in the ridge to its north , causing the hurricane to turn to the northwest . The combination of enhanced outflow from the trough and very warm waters

allowed Ivan to maintain Category 5 status for 30 hours . Early on September 14 the hurricane passed through the Yucatán Channel about 17 miles ( 28 km ) southwest of Cabo San Antonio , Cuba , with the eastern portion of the eyewall crossing the western portion of the island . Only the extreme western portion of the island experienced hurricane force winds , although rainfall from the hurricane was reported across the island .

= = Gulf of Mexico and Alabama landfall = =

After entering the southern Gulf of Mexico , Hurricane Ivan weakened to Category 4 status by 0600 UTC on September 14 . As it gradually turned to the north , southwesterly flow from a large trough over the central United States increased wind shear over the hurricane . An eyewall replacement cycle , along with dry air and restricted outflow , contributed to the weakening . By late on September 14 the weakening trend ceased as the eyewall became better defined , and Ivan was expected to restrengthen slightly over an area of warmer water temperatures . The eye diameter expanded to 60 miles ( 95 km / h ) , though concurrently westerly wind shear and dry continued to increase . As Ivan approached the Gulf Coast of the United States , Hurricane Hunters reported erosion of the southern portion of the eyewall , and cooler waters just offshore contributed to further weakening . At around 0650 UTC on September 16 , Hurricane Ivan made landfall just west of Gulf Shores , Alabama with an intensity of 120 mph ( 195 km / h ) ; the strongest winds occurred over a narrow area near the southern Alabama and western Florida border . Its landfall was accompanied by a 10 ? 15 feet ( 3 ? 4 @. @ 5 m ) storm surge from Destin , Florida westward to Mobile Bay .

Upon moving ashore , the National Hurricane Center expected the forward path of Ivan to be blocked , and accordingly forecast the hurricane to stall in the southern Appalachian Mountains before dissipating . As the hurricane crossed Mobile Bay it turned to the north @-@ northeast , and within twelve hours Ivan rapidly weakened to tropical storm status . The circulation became less @-@ defined , and early on September 17 the cyclone deteriorated into a tropical depression over northeastern Alabama . Ivan accelerated to the northeast ahead of an approaching cold front , dropping heavy rainfall along its path and also producing a widespread tornado outbreak from Alabama through Maryland . Late on September 18 , the remnants of Ivan transitioned into an extratropical low as it merged with the cold front over the Delmarva Peninsula .

= = Redevelopment and demise = =

After becoming an extratropical low , the remnants of Ivan turned to the southeast and emerged into the Atlantic Ocean , due to the building of an upper @-@ level ridge to its east . As an extratropical cyclone , Ivan remained identifiable in both surface and upper @-@ level data , and the system turned south and southwestward over the subsequent days . By September 20 , the system was located off the east coast of Florida , producing scattered thunderstorms ; unfavorable wind shear prevented tropical redevelopment , though forecasters indicated the possibility for more favorable conditions a few days later . On September 21 the low crossed southern Florida and emerged into the Gulf of Mexico , and as it moved across the warm waters of the region the low began to re @-@ acquire tropical characteristics ; the low @-@ level circulation became increasingly better defined , and convection redeveloped over the center . Based on reports from Hurricane Hunters , it is estimated the low redeveloped into Tropical Depression Ivan late on September 22 while located about 175 miles ( 280 km ) south @-@ southeast of the mouth of the Mississippi River .

In its first advisory on the re @-@ developed cyclone , the National Hurricane Center classified the system Ivan " after considerable and sometimes animated in @-@ house discussion of [ its demise ] ... in the midst of a low @-@ pressure and surface frontal system over the eastern United States ... based primarily on the reasonable continuity observed in the analysis of the surface and low @-@ level circulation . " Despite unfavorable shear and its disorganized cloud structure , the cyclone intensified to tropical storm status early on September 23 , based on Hurricane Hunter reports . As an area of deep convection developed over the center , Ivan reached winds of 60 mph ( 95 km / h ) ,

though the winds decreased as thunderstorm activity diminished . Ivan weakened to a tropical depression at 0000 UTC on September 24 , and two hours later it moved ashore near Holly Beach , Louisiana . Initial computer models forecast the low @-@ level circulation to turn southwestward and re @-@ emerge into the Gulf of Mexico . However , the storm rapidly weakened over land , and by 1200 UTC on September 24 Ivan degenerated into a remnant low pressure area over southeastern Texas . The low turned to the south and the circulation dissipated early on September 25 . The remnant trough reached the northwestern Gulf of Mexico later that day , briefly producing scatter thunderstorms before it diminished .

= = Records = =

Reaching Category 3 status on the Saffir @-@ Simpson Hurricane Scale at 10 @.@ 2 ° N , Ivan became the southernmost major hurricane on record . Additionally , the hurricane attained Category 4 and Category 5 status further south than any other North Atlantic hurricane , at 10 @.@ 6 ° N and 13 @.@ 7 ° N , respectively . At the time , Ivan was the sixth most intense Atlantic hurricane on record ; it has since dropped to tenth . Throughout its duration , Ivan maintained winds of major hurricane status or greater for a total of 10 days , establishing an Atlantic hurricane record . Lasting as a tropical cyclone for a total of 450 hours , Ivan was the tenth longest tracked Atlantic hurricane on record .

Upon making its first landfall in the United States , the hurricane spawned a total of 117 tornadoes , which is the largest tornado outbreak associated with a tropical cyclone ; this broke the previous record of 115 set by Hurricane Beulah in 1967 .