NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

HURRICANE INGRID

(AL102013)

12 – 17 September 2013

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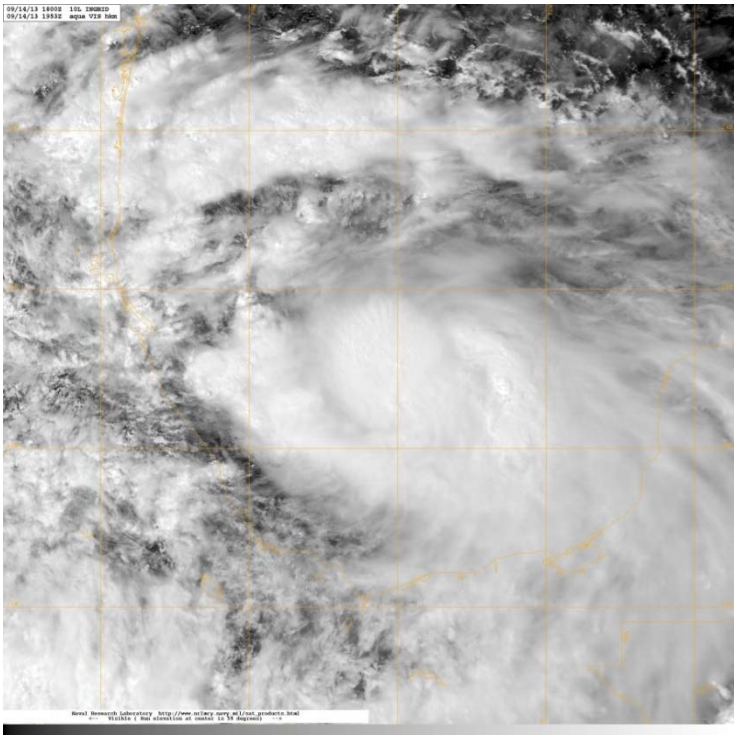
National Hurricane Center
5 February 2014
(revised 14 April 2014 for the death toll in Mexico)



VISIBLE IMAGE OF INGRID FROM THE MODIS INSTRUMENT ON THE NASA AQUA SATELLITE AT 1953 UTC 13 SEPTEMBER. IMAGE COURTESY OF NASA AND NRL MONTEREY.

Ingrid was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) over the southwestern Gulf of Mexico that made landfall as a tropical storm in northeastern Mexico. In combination with Eastern Pacific Hurricane Manuel, it caused widespread flooding and many casualties in Mexico.

Hurricane Ingrid

12 – 17 SEPTEMBER 2013

SYNOPTIC HISTORY

The origin of Ingrid was complicated. One contributor was a tropical wave that moved westward from the coast of Africa on 28 August and showed little distinction through 1 September. On 2 September, shower activity increased near the northern end of the wave axis. This area of weather would eventually be absorbed into Tropical Storm Gabrielle, which was developing near and north of Puerto Rico during the 3 - 7 September period. The southern part of the wave continued westward and eventually moved into a large area of low-level cyclonic flow extending from the western Caribbean Sea across Central America into the eastern north Pacific. The combination of this flow and the wave produced two areas of disturbed weather between 8-10 September. One, over the Pacific, moved westward and eventually helped spawn Hurricane Manuel. The second, which appeared over the northwestern Caribbean Sea on 9 September, became Ingrid.

Slow development of the Caribbean disturbance led to formation of a low pressure area on 11 September. While the system showed signs of organization before moving over the Yucatan Peninsula later that day, surface observations indicate that it had not developed into a tropical cyclone. The low moved west-northwestward, with the center apparently reforming over the Bay of Campeche early on 12 September. Subsequent development led to the formation of a tropical depression around 1800 UTC that day about 150 n mi east-northeast of Veracruz, Mexico. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

The depression initially moved westward, but turned toward the west-southwest on 13 September while the cyclone intensified into a tropical storm. Later that day, Ingrid made a hairpin turn when it was centered about 50 n mi east of Veracruz. On 14 September a combination of a mid/upper-level trough over northeastern Mexico and low/mid-level ridging over the southeastern United States steered Ingrid north-northeastward and then northward. Although the trough and upper-level outflow from Manuel caused moderate westerly vertical wind shear over Ingrid, the cyclone managed to intensify into a hurricane later on 14 September. Thereafter, it reached a peak intensity of 75 kt early on 15 September while centered about 215 n mi southeast of La Pesca, Mexico.

The hurricane turned northwestward near the time of peak intensity, and this motion continued for the rest of the day. On 16 September, a mid-level ridge over Texas caused Ingrid to turn west-northwestward. Increasing vertical shear caused the cyclone to weaken below

[1] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

hurricane strength, and it is estimated that the maximum winds had decreased to 55 kt when the center made landfall just south of La Pesca around 1115 UTC that day. After landfall, Ingrid moved slowly westward until it dissipated over northeastern Mexico on 17 September.

METEOROLOGICAL STATISTICS

Observations in Ingrid (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command, the NOAA Aircraft Operations Center, and the NASA Hurricanes and Severe Storms Sentinel program. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Tropical Rainfall Measuring Mission (TRMM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Ingrid, as were data and imagery from coastal radars in Mexico and southern Texas.

Winds and Pressure

There were 16 air reconnaissance missions flown in association with Ingrid – 8 by the WC-130s of the 53rd Weather Reconnaissance Squadron, 5 by the NOAA P-3s, 2 by the NOAA G-IV jet, and 1 by the NASA Global Hawk. The maximum flight-level wind was 76 kt (850 mb) at 1404 UTC 14 September, and there were three bias-corrected SFMR surface wind estimates near 75 kt between 2255-2315 UTC 14 September (uncorrected 75-78 kt data shown in Figure 2). In addition, a dropsonde at 2300 UTC 14 September reported an instantaneous surface wind of 82 kt, with layer averages over the lowest 150 m suggesting 1-min surface winds of 70-75 kt. These data are the basis for the estimated peak intensity of 75 kt. The landfall intensity of 55 kt is based on a 850-mb flight-level wind of 65 kt and a bias-corrected SFMR wind of 49 kt measured northeast of the center.

The lowest aircraft-reported pressure was 984 mb at 2039 UTC 14 September by a dropsonde with a 16-kt surface wind. In addition, a dropsonde at 2350 UTC 14 September reported 986 mb with a surface wind of 27 kt. These data are the basis for the estimated 983 mb minimum pressure. The lowest pressure observed at a surface station was 993.0 mb from the EPEMX buoy Metoceánica at 0600 UTC 14 September (Table 2).

Ingrid brought tropical-storm conditions to portions of the northeastern coast of Mexico. An automated station at La Pesca reported sustained winds of 43 kt at 1045 UTC 16 September, with a peak gust of 57 kt. The station reported a minimum pressure of 993.8 mb at 1145 UTC that day. The PEMEX buoy CS1 located northeast of La Pesca reported sustained winds of 46 kt and a peak gust of 61 kt (3.0 m anemometer height) at 0940 UTC 16 September,

along with a minimum pressure of 999.5 mb 30 min later. Sustained tropical-storm-force winds also occurred along the Mexican coast near Veracruz late on 13 September.

In addition to the impacts in Mexico, a few gusts to tropical-storm-force occurred in squalls along the lower Texas coast.

There was one ship report of tropical-storm-force winds from Ingrid. The **Eagle Anaheim** (call sign S6TF) reported 37-kt winds and a pressure of 1004.5 mb at 2200 UTC 14 September.

Storm Surge[2]

Ingrid likely caused above normal tides near and to the north of the landfall point in northeastern Mexico. However, no data are available from this area. Tides of about 1 ft above normal were reported along the lower Texas coast.

Rainfall and Flooding

A combination of Manuel, Ingrid, and the large-scale low-level southwesterly flow caused widespread heavy rains over large portions of Mexico, with the heaviest rains associated with Ingrid likely occurring over the Mexican states of Tabasco, Veracruz, and Tamaulipas. In these areas, Tuxpan reported a rainfall total of 20.11 in during the period between 11-20 September (Table 2), Presa Vicente Guerrero reported a total of 19.77 in, and there are numerous other reports in excess of 10 in. These rains in Mexico produced widespread damaging flooding and mudslides. In addition, Ingrid produced 1-3 inches of rain over portions of southern Texas.

Tornadoes

There were no tornadoes reported in association with Ingrid.

CASUALTY AND DAMAGE STATISTICS

Ingrid and Manuel collectively caused significant damage and casualties[3] in Mexico. The Meteorological Service of Mexico and the Mexican Civil Protection Agency report that 32

[2] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

people died due to Ingrid. Most of the fatalities were due to heavy rains and mudslides. However, a breakdown of the deaths into direct and indirect categories is not available. Data compiled by the AON Benfield company suggests that damage to insured property in Mexico from Ingrid was $230 million USD.

FORECAST AND WARNING CRITIQUE

The genesis of Ingrid was generally well forecast. The possibility that a disturbance could form in the Bay of Campeche was first mentioned in the experimental extended (120-h) Tropical Weather Outlook (TWO) on 7 September, five days before genesis occurred. Ingrid's pre-cursor disturbance was first mentioned in the short-range TWO on 10 September about 60 h before genesis. The lead time provided for each genesis likelihood category, beginning with the time that the system was introduced into the TWO, is given in the table below. One factor affecting the genesis forecasts was the uncertainty regarding whether the disturbance would move far enough away from land over the Bay of Campeche to allow development to occur.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<30%)	60	120
Medium (30%-50%)	36	90
High (>50%)	12	66

A verification of NHC official track forecasts for Ingrid is given in Table 3a. Official forecast track errors were lower than the mean official errors of the previous 5-yr period at 24, 36, 72, and 96 h, and comparable to those errors for 12 and 48 h. However, the number of forecasts was relatively small. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. While the sample size is again small, the fixed and variable consensus models (TCON and TVCN), as well as the Florida State University Superensemble (FSSE), had lower errors than the official forecasts for 24-48 h. Although the official track forecasts were generally good, there were three notable sources of error. First, the early forecasts on 12-13 September did not show Ingrid moving as far west-southwestward as it actually did. Second, when it was forecast that Ingrid would turn northward on 14 September, the cyclone actually moved north-northeastward. Finally, while it was anticipated that the

[3] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect" deaths.

cyclone would turn westward and make landfall in eastern Mexico, the actual westward turn was not as sharp as forecast.

A verification of NHC official intensity forecasts for Ingrid is given in Table 4a. Official forecast intensity errors were greater than the mean official errors for the previous 5-yr period at all times except 72 h. However, the errors for climatology and persistence (OCD5) were also larger than those of the previous 5-yr period, indicating that Ingrid was harder to forecast than normal. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. Most of the intensity guidance had lower errors than the official forecasts. There were two sources of error in the intensity forecasts. First, the early forecasts did not predict Ingrid to become a hurricane due to the westerly shear. Second, later forecasts did not capture the slow decay that occurred after Ingrid reached peak intensity and thus had a high bias.

Watches and warnings associated with Ingrid are given in Table 5. The Government of Mexico issued a hurricane watch for the landfall area about 60 h before the center of Ingrid made landfall, while a hurricane warning was issued 39 h before landfall.

ACKNOWLEDGEMENTS

Fabián Vázquez Romaña of Petroleos Mexicanos (PEMEX) provided the PEMEX buoy data. René Lobato Sánchez of the National Meteorological Service of Mexico provided the automated station and rainfall data from Mexico. Rex Hervey of the National Data Buoy Center provided the NOAA buoy and coastal automated station data. John Cangialosi of the Hurricane Specialist Unit created the best track map.

Table 1. Best track for Hurricane Ingrid, 12 – 17 September 2013.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
12 / 0600	19.3	92.2	1006	25	low
12 / 1200	19.6	92.9	1005	30	"
12 / 1800	19.7	93.6	1004	30	tropical depression
13 / 0000	19.7	94.1	1003	30	"
13 / 0600	19.6	94.6	1002	30	"
13 / 1200	19.3	95.1	1000	35	tropical storm
13 / 1800	19.1	95.3	996	40	"
14 / 0000	19.3	95.3	993	50	"
14 / 0600	19.6	95.1	990	55	"
14 / 1200	20.3	94.6	989	60	"
14 / 1800	21.0	94.4	986	65	hurricane
15 / 0000	21.6	94.7	983	75	"
15 / 0600	22.0	95.2	985	75	"
15 / 1200	22.4	95.6	989	65	"
15 / 1800	22.7	95.9	987	65	"
16 / 0000	23.0	96.2	989	70	"
16 / 0600	23.4	96.9	990	60	tropical storm
16 / 1115	23.7	97.7	991	55	"
16 / 1200	23.7	97.8	991	55	"
16 / 1800	23.7	98.7	998	40	"
17 / 0000	23.7	99.2	1006	25	tropical depression
17 / 0600	23.7	99.7	1008	20	low
17 / 1200					dissipated
15 / 0000	21.6	94.7	983	75	Maximum wind and minimum pressure
16 / 1115	23.7	97.7	991	55	Landfall just south of La Pesca, Mexico

Table 2. Selected surface observations for Hurricane Ingrid, 12 – 17 September 2013.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in) [c]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)	
Mexico						
Automated Stations						
La Pesca (23.99N 97.77W)	16/1145	993.8	16/1045	43	57	14.46
Other Sites						
Acatlan (19.70N 96.84W)						10.76
Altotonga (19.76N 97.23W)						17.50
Alvarado Radar (18.72N 95.63W)						11.34
Angel R. Cabada (18.58N 95.44W)						16.30
Boca Toma Chairel (22.24N 97.88W)						11.98
El Barretal (24.10N 99.22W)						18.84
El Radual (20.16N 96.71W)						16.77
La Servilleta (22.83N 99.12W)						17.47
Los Hules (21.16N 98.27W)						11.79
Magueyes (24.57N 99.55W)						19.08
Martinez de la Torre (20.07N 97.05W)						16.11
Miguel Hildago (24.25N 99.43W)						17.72
Misantla (19.93N 96.83W)						15.97
Observatorio Altamira (22.39N 97.93W)						10.71
Observatorio Ciudad Victoria (23.73N 99.13W)						14.47
Padilla (24.05N 98.90W)						16.95
Paso De Molina (23.73N 98.75W)						19.38
Pilon (24.14N 98.90W)						15.55
Platon Sanchez (21.29N 98.34W)						10.89
Presa El Moralillo (21.18N 97.81W)						18.35

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in) [c]
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)	
Presa Pedro J. Mendez (24.23N 99.55W)						18.85
Presa Vicente Guerrero (23.97N 98.55W)						19.77
Rio Frio (22.85N 99.00W)						10.70
San Fernando (24.84N 98.16W)						11.48
Shiuapan (18.45N 95.18W)						17.71
Sontecomapan (18.52N 95.03W)						11.34
Soto La Marina (23.77N 98.21W)						18.63
Tampico (22.24N 97.88W)						12.39
Terrerillos (21.04N 98.14W)						10.74
Tomata (19.92N 97.22W)						15.41
Tuxpan (20.96N 97.4W)						20.11
Villagran (24.30N 99.49W)						17.75
Coastal-Marine Automated Network (C-MAN) Sites						
Sacrifice Island (SACV4) (19.17N 96.09W) (9.0 m)	13/2300	999.6	13/2330	35 (10-min)	41	
Veracruz (VERV4) (19.20N 96.11W) (9.0 m)	13/2300	999.4	13/2320	32 (10-min)	41	
Buoys						
Mexico Buoy CS1 (23.88N 97.36W) (3.0 m)	16/1010	999.5	16/0940	46	61	
Mexico Buoy Metoceánica (19.50N 95.00W) (3.0 m)	14/0600	993.0	14/0800	35	51	
NOAA Buoy 42002 (25.79N 93.67W) (10.0 m)	14/0950	1007.8	15/1510	32 (10-min)	41	
NOAA Buoy 42055 (22.20N 94.00W) (5.0 m)	14/2209	1001.1	15/0053	37 (1-min)	43	

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.
[b] Rainfall totals from Mexico are for the period 11-20 September.

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Ingrid, 12 – 17 September 2013. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	28.7	**43.9**	**47.6**	80.6	**80.3**	**100.0**	
OCD5	47.3	81.7	116.8	164.1	120.9	152.7	
Forecasts	16	14	12	10	6	2	
(AL) OFCL (2008-12)	28.6	45.8	62.2	78.6	116.6	160.0	
(AL) OCD5 (2008-12)	47.5	99.7	161.4	224.0	329.7	417.5	

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Ingrid, 12 – 17 September 2013. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	27.6	42.9	50.4	77.9			
OCD5	42.9	80.4	118.4	176.3			
GFSI	41.2	61.0	86.8	100.8			
GHMI	36.1	57.1	70.2	**75.5**			
HWFI	40.8	55.9	87.5	115.2			
EGRI	34.1	56.0	87.0	130.8			
EMXI	30.1	**39.7**	**48.8**	87.4			
CMCI	33.9	79.3	114.3	135.5			
TCON	33.0	**41.5**	**42.0**	**58.2**			
TVCA	31.3	**37.2**	**37.3**	**59.0**			
FSSE	33.8	**40.0**	**44.6**	**66.8**			
AEMI	39.4	55.0	67.2	83.6			
BAMS	73.6	159.0	219.0	261.8			
BAMM	56.5	123.3	177.5	233.4			
BAMD	38.0	70.0	97.9	143.7			
Forecasts	13	9	9	7			

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Ingrid, 12 – 17 September 2013. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	8.4	14.3	15.8	17.5	**13.3**	20.0	
OCD5	7.2	13.9	20.8	26.2	21.2	21.0	
Forecasts	16	14	12	10	6	2	
(AL) OFCL (2008-12)	6.6	10.1	12.2	14.1	15.4	15.1	
(AL) OCD5 (2008-12)	7.8	11.6	14.0	15.6	17.9	18.0	

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Ingrid, 12 – 17 September 2013. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	10.0	15.5	14.4	13.6	11.7		
OCD5	**7.8**	15.6	21.8	25.6	22.7		
HWFI	**8.0**	**10.9**	**12.7**	16.9	15.0		
GHMI	10.6	**12.7**	16.1	17.9	12.0		
DSHP	**8.8**	**12.9**	**13.9**	**12.4**	**6.7**		
LGEM	**9.2**	**14.7**	16.7	17.4	**6.3**		
ICON	**9.0**	**11.2**	**13.1**	**13.4**	**9.7**		
IVCN	**9.0**	**11.2**	**13.1**	**13.4**	**9.7**		
FSSE	**8.8**	**10.9**	**14.0**	14.3	**9.7**		
Forecasts	13	11	9	7	3		

Table 5. Watch and warning summary for Hurricane Ingrid, 12 – 17 September 2013.

Date/Time (UTC)	Action	Location
12 / 2100	Tropical Storm Warning issued	Coatzacoalcos to Barra de Nautla
13 / 1500	Tropical Storm Warning modified to	Coatzacoalcos to Cabo Rojo
13 / 1500	Tropical Storm Watch issued	North of Cabo Rojo to La Pesca
14 / 0000	Tropical Storm Watch changed to Hurricane Watch	North of Cabo Rojo to La Pesca
14 / 2100	Hurricane Warning issued	Cabo Rojo to La Pesca
14 / 2100	Tropical Storm Warning modified to	Tuxpan to Cabo Rojo
14 / 2100	Tropical Storm Warning issued	North of La Pesca to Bahia Algodones
15 / 0300	Hurricane Watch issued	North of La Pesca to Bahia Algodones
15 / 0300	Tropical Storm Warning modified to	North of La Pesca to Rio San Fernando
16 / 1200	Hurricane Watch discontinued	All
16 / 1200	Hurricane Warning discontinued	All
16 / 1200	Tropical Storm Warning modified to	Cabo Rojo to Rio San Fernando
16 / 1500	Tropical Storm Warning modified to	La Cruz to Rio San Fernando
16 / 2100	Tropical Storm Warning discontinued	All

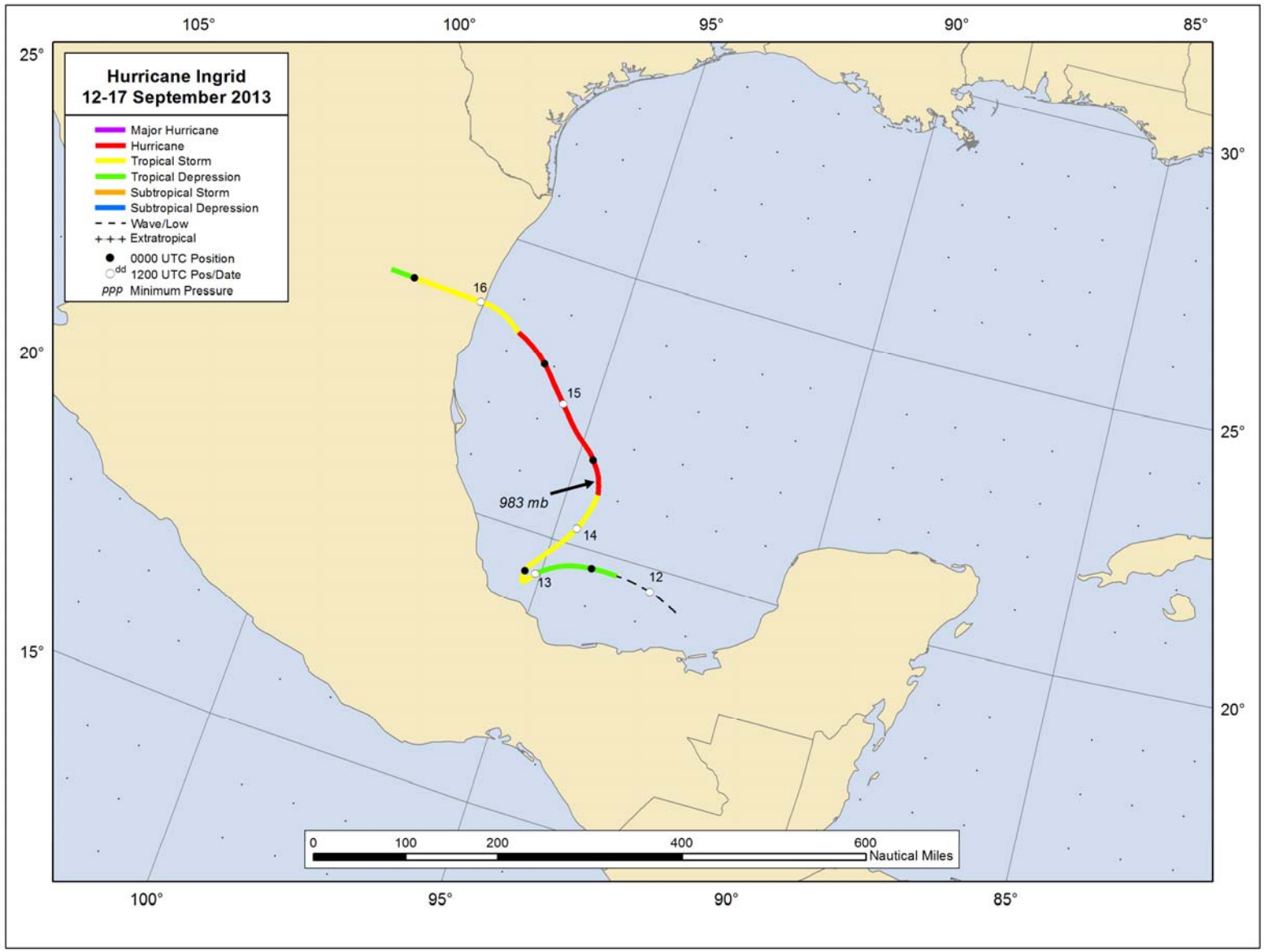


Figure 1. Best track positions for Hurricane Ingrid, 12 – 17 September 2013.

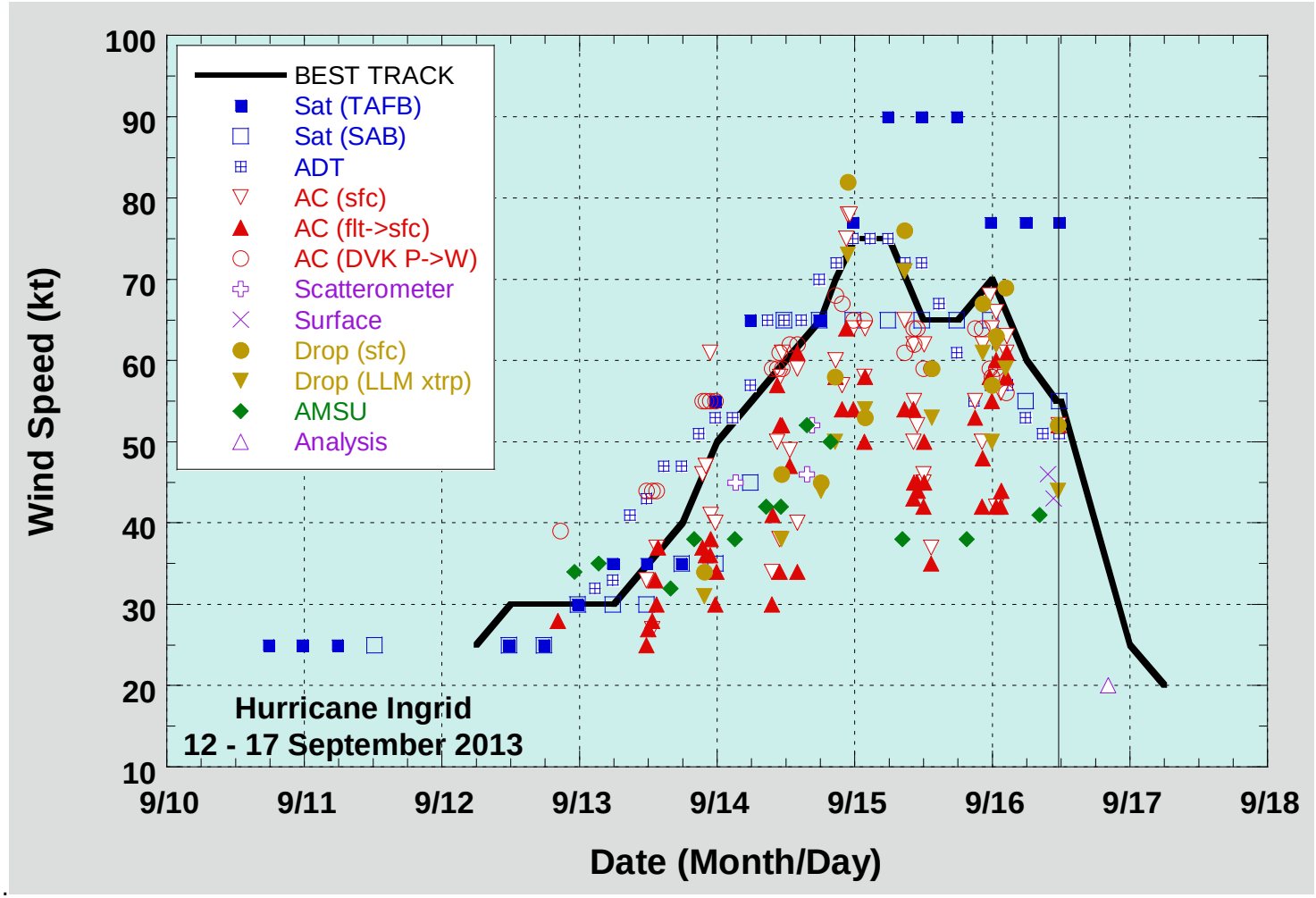


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Ingrid, 12 – 17 September 2013. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and the solid vertical line corresponds to landfall.

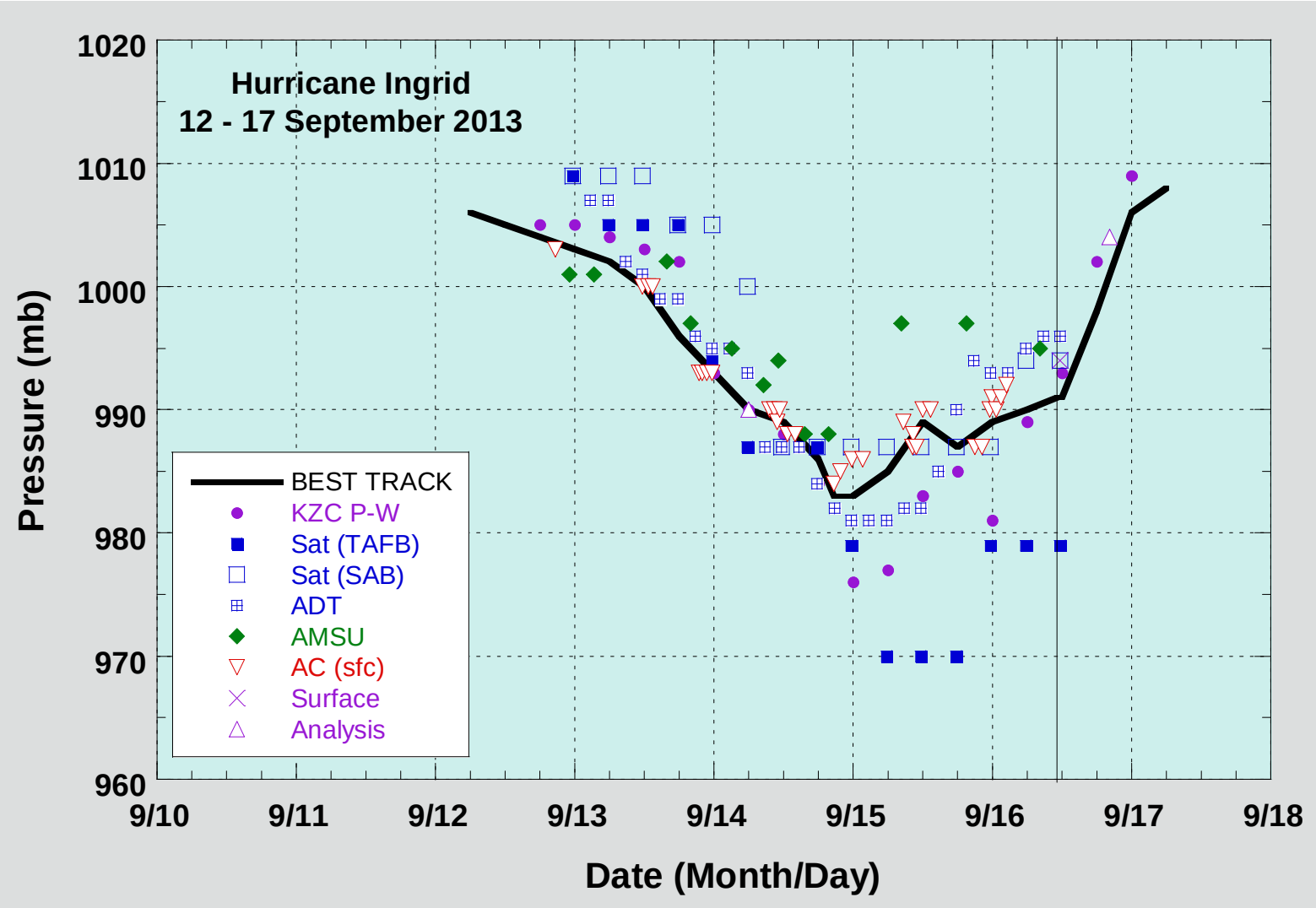


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Ingrid, 12 – 17 September 2013. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and the solid vertical line corresponds to landfall.