

**On-line Appendix for**

**A Reanalysis of the 1921 to 1930 Atlantic Hurricane Database**

Christopher W. Landsea\*, Steve Feuer\*, Andrew Hagen\*\*, David A. Glenn\*\*\*, Nicholas T. Anderson\*\*, James Sims\*\*\*\*, Ramon Perez<sup>&</sup>, and Michael Chenoweth<sup>&&</sup>

\*NOAA/NWS/NCEP/National Hurricane Center, Miami, Florida, USA; \*\*University of Miami, Miami, Florida, USA; \*\*\*NOAA/NWS/WFO Morehead City, Morehead City, North Carolina, USA; \*\*\*\*NOAA/NWS/NCEP/Environmental Modeling Center, Camp Springs, Maryland, USA, <sup>&</sup>Institute of Meteorology, Havana, Cuba; <sup>&&</sup>Independent Scholar, Elkridge, Maryland

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All Atlantic basin tropical storms and hurricanes in the new best track database are accompanied by a “metadata file”. This file consists of a day-by-day listing of peak meteorological observations and previous estimates of the storm’s position and intensity. The metadata also contains a descriptive paragraph about the particular methodology employed for making changes in the genesis, track, intensity and decay of that TC including what sources were crucial for revising the best track, whether or not a wind-pressure relationship was utilized, if wind decay models were used for inland wind estimates, and any other pertinent information. All of the tropical storms and hurricanes for the period of 1921 to 1930 are considered “UNNAMED”. However, many of these storms have been recognized by various informal names. These are included in the metadata file when at all possible. The following is an example of a single metadata entry for Storm #4, 1928 – the "San Felipe/Lake Okeechobee Hurricane". After the metadata, the Comments from and Replies to the NHC Best Track Change Committee for this single hurricane are provided. Table A1 indicate significant (hurricane force and greater) reports collected for this system and made available in the raw database. Figure A1 shows the revised and original track for the 1928 San Felipe/Lake Okeechobee hurricane.

Storm #4, 1928 (The San Felipe/Lake Okeechobee Hurricane) Metadata

1928/04 - 2010 REVISIONS:

24775 09/06/1928 M=15 4 SNBR= 553 NOT NAMED XING=1 SSS=4  
 24775 09/06/1928 M=16 4 SNBR= 553 NOT NAMED XING=1 SSS=4  
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24780	09/06*	0	0	0	0*	0	0	0	0*137	204	35	0*138	221	35	0
24780	09/06*142	170	30	0*141	185	30	0*140	200	35	0*138	216	40	0		
	***	***	**	***	***	**	***	***			***	**			
24785	09/07*139	239	35	0*140	257	35	0*141	275	35	0*142	294	35	0		
24785	09/07*137	232	45	0*136	248	50	0*135	265	55	0*135	282	60	0		
	***	***	**	***	***	**	***	***	**	***	***	**			

24790	09/08*	144	315	35	0*146	335	40	0*147	352	40	0*148	367	40	0	
24790	09/08*	135	300	60	0*136	317	60	0*137	335	60	0*138	352	60	0	
	***	***	**		***	***	**	***	***	**	***	***	**		
24795	09/09*	148	382	45	0*148	396	50	0*149	411	50	0*150	426	55	0	
24795	09/09*	139	370	60	0*140	387	60	0*142	405	60	0*143	422	60	0	
	***	***	**		***	***	**	***	***	**	***	***	**		
24800	09/10*	151	440	55	0*152	454	60	0*153	469	60	0*154	486	65	0	
24800	09/10*	144	440	60	0*145	457	60	0*147	475	60	0*149	492	65	0	
	***		**		***	***		***	***		***	***			
24805	09/11*	155	505	70	0*155	525	75	0*156	542	80	0*157	557	85	0	
24805	09/11*	152	509	70	0*155	526	75	0*158	542	80	0*159	558	85	0	
	***	***			***			***			***	***			
24810	09/12*	158	572	95	0*159	586	100	0*160	599	105	0*162	611	110	940	
24810	09/12*	159	573	95	0*159	588	100	0*160	603	110	0*162	615	120	940	
	***	***			***			***	***		***	***			
24815	09/13*	165	623	115	0*169	635	120	0*174	647	135	0*179	658	140	931	
24815	09/13*	165	626	130	0*170	636	135	0*175	648	140	0*180	659	140	931	
	***	***			***	***	***	***	***	***	***	***			
24820	09/14*	185	670	140	0*190	680	135	0*196	691	135	0*200	700	135	0	
24820	09/14*	184	669	120	941*189	680	125	0*194	690	130	0*199	700	135	0	
	***	***	***	***	***		***	***	***	***	***				
24825	09/15*	206	708	135	0*213	716	135	0*222	727	135	0*228	736	135	0	
24825	09/15*	207	708	135	0*215	717	135	0*222	727	135	0*229	738	135	0	
	***				***	***					***	***			
24830	09/16*	235	748	135	0*243	760	135	0*251	772	135	0*258	783	130	0	
24830	09/16*	237	750	135	0*245	763	135	0*253	776	135	0*260	788	130	0	
	***	***			***	***		***	***		***	***			
24835	09/17*	265	795	130	929*271	801	115	0*278	815	110	955*288	820	90	0	
24835	09/17*	267	800	125	929*272	811	100	0*278	820	85	0*286	822	75	0	
	***	***	***	***	***	***	***	***	***	***	***	***	***	**	
24840	09/18*	300	819	80	974*313	815	75	0*325	808	60	978*331	800	60	0	
24840	09/18*	294	820	70	0*301	817	65	977*311	811	75	976*324	805	75	977	
	***	***	**	***	***	***	**	***	***	***	**	***	***	***	***
24845	09/19*	341	786	50	981*349	777	45	0*358	770	40	989*370	770	40	0	
24845	09/19*	338	792	60	0*348	783	60	0E358	775	70	0E368	773	60	0	
	***	***	**	***	***	***	**	*	***	**	*****	***	**		
24850	09/20*	385	775	40	1002E402	780	40	0E420	784	35	1008E433	790	35	0	
24850	09/20E	380	775	50	0E397	780	40	0E415	790	35	1008E435	792	30	0	
	****		**	***				***	***		***	***	**		

(The 21st is new to HURDAT.)

24850	09/21E	455	790	25	1002*	0	0	0	0*	0	0	0	0	0	0
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24855	HRCFL4				DFL2	GA1	SC1								
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24855	HRCFL4	BFL3	AFL1	DFL1	GA1	SC1									
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U.S. Continental Hurricanes:

#/Date	Time	Lat	Lon	Max Wind	Saffir Simpson	RMW	Central Pressure	States Affected
9/17/1928	0000Z	26.7N	80.0W	125kt	4	28nmi	929mb	CFL4, BFL3, AFL1, DFL1
9/18/1928	1900Z	32.5N	80.3W	75kt	1	35nmi	976mb	GA1, SC1

Minor alterations are introduced to the track, but major changes are made to the intensity shown in McAdie et al. (2009). Evidence for these alterations comes from the Historical Weather Map series, the COADS ship database, individual station and ship data from the National Climate Data Center (NCDC), *Monthly Weather Review*, Dunn and Miller (1960), Perez (1971), Schwerdt et al. (1979), Ho et al. (1987), Jarrell et al. (1992), Barnes (1998), Roth and Cobb (2001), Pfof (2003), Kleinberg (2003) and Caribbean observations provided by Mike Chenoweth and Jose Colon. Daniel Gladstein also made significant contributions toward the reanalysis of this cyclone.

September 6: HWM does not analyze a closed low on this day. HURDAT listed this as a 35 kt tropical storm at 13.7N, 20.4W. Ship highlights: No gales or low pressures.

September 7: HWM does not analyze a closed low on this day. HURDAT listed this as a 35 kt tropical storm at 14.1N, 27.5W. Ship highlights: 50 kt S at 14 UTC at 13.5N, 26.5W (COA); 30 kt NNW and 1003 mb at 06 UTC at 13.5N, 26.5W (COA).

September 8: HWM does not analyze a closed low on this day. HURDAT listed this as a 40 kt tropical storm at 14.7N, 35.2W. Ship highlights: No gales or low pressures do to lack of ships in the area. Land highlights: No gales or low pressures in the Cape Verde Islands.

September 9: HWM does not analyze a closed low on this day. HURDAT listed this as a 50kt tropical storm at 14.9N, 41.1W. Ship highlights: No gales or low pressures due to lack of ships in the area.

September 10: HWM analyzes a closed low of at most 1010 mb centered near 12.5N, 44.5W. HURDAT listed this as a 60 kt tropical storm at 15.3N, 46.9W. Ship highlights: 50 kt WSW and 1001 mb at 14 UTC at 14.5N, 48.2W (NCDC); 45 kt SW and 1003 mb at 15 UTC at 14.3N, 48.2W (NCDC); 45 kt NNW and 1004 mb at 12 UTC at 14.8N, 48.1W (NCDC). "On the morning of September 10 the S.S. Commack, in latitude 17N, longitude 48.3W, reported a barometer reading of 29.94 inches with wind from the northeast, force 7 [30 kt]... although this hurricane undoubtedly formed near the Cape Verde Islands" (MWR). "At 2 pm the same date the S.S. Clearwater, in latitude 14N, longitude 51W, reported a barometer reading of 29.90 inches with wind from the northwest, force 5 [20 kt], and a pressure fall of 0.10 inch in 2 hours" (MWR).

September 11: HWM analyzes a closed low of at most 1005 mb centered near 14.2N, 52.6W. HURDAT listed this as an 80 kt hurricane at 15.6N, 54.2W. Ship highlights: 50 kt SSE and 1011 at 15 UTC at 16.0N, 53.0W (NCDC); 50 kt NE and 1011 mb at 16 UTC at 17.0N, 56.0W (MWR); 999 mb at 08 UTC at 16.0N, 53.0W (NCDC). "At 8 pm of the same date [the 10th] the S.S. Clarissa in latitude 13N, longitude 51W, reported a barometer reading of 29.84 inches with wind from the west, force 6 [25 kt]. The reports from these three vessels definitely established the fact that a tropical cyclone of unknown intensity was moving almost directly westward, being central at 8 pm [the 10th] nearly 600 miles east-northeast of Bridgetown. The following morning a report

from S.S. Inanda, in latitude 17N, 56W, was received, the barometer reading 29.86 inches with wind from the northeast, force 10 [50 kt]" (MWR).

September 12: HWM analyzes a closed low of at most 1005 mb centered near 14.6N, 60.5W. HURDAT listed this as a 105 kt hurricane at 16.0N, 59.9W. Ship highlights: 50 kt W and 999 mb at 19 UTC at 14.7N, 61.2W (MWR); 45 kt WNW and 1001 mb at 12 UTC at 14.6N, 61.1W (COA/MWR). Land highlights: 40 kt NE at 2320 UTC at San Juan, Puerto Rico at 18.5N, 66.0W (Perez); 4 observations of 940 mb all in the eye between 1730 UTC and 1830 UTC in Guadeloupe at 16.2N, 61.5W (MWR/NCDC); 3 of those observations were at Agronomique, Guadeloupe, and 1 was at Pointe A'Pitre, Guadeloupe, both at 16.2N, 61.5W; 955 mb at Martinique at 2230 UTC (Chenoweth); 35 kt W and 993 mb at 17 UTC at Dominica at 15.3N, 61.4W (MWR). 10-12 foot tidal surge at ~1830 UTC at Agronomique, Guadeloupe at 16.2N, 61.5W (NCDC). Regarding the intensity: "By 8 pm [the 11th] pressure had begun to fall in the Lesser Antilles and the wind at Bridgetown, Barbados, had backed from northeast to northwest. At 8 am of the 12th the barometer at Roseau, Dominica, read 29.44 inches and the wind was 24 mph from the northwest. A report received by mail from Guadeloupe, shows that the center of the hurricane passed close to that place about noon of the 12th with a barometer reading of 27.76 inches. Press dispatches from Paris, France, indicate that great destruction was wrought by the hurricane in Guadeloupe, which is a French possession. The English islands of St. Kitts and Montserrat also suffered heavy losses" (MWR). "Dominica reported lowest barometer at 1 pm of the 12th of 29.32 inches (993 mb) with a west wind of 40 mph" (MWR). "Center was as wide as the distance between Duquerry and Ste. Anne, i.e., about 14 miles. The storm was thus moving at 14 mph. The central or calm of dread of the hurricane was variously estimated to be from 14 to 25 miles in diameter and to occupy 20

minutes to over an hour in crossing a given point..." (NCDC - Station Agronomique de la Guadeloupe). "That the storm was severe as was indicated by the large number of dead (apparently well over 1300) and the heavy material losses which are estimated to be over four million pounds sterling. At 1:30 pm the barometer had reached its minimum of 940 mb, about which point it oscillated until 2:30 pm, when it was still at 940 mb. This period was marked by a slight calm. The wind decreased somewhat in violence and the rain was lighter. Between 2 pm and 2:30 the calm was, for a short period, more marked, and the sky cleared up somewhat, the sun almost piercing the clouds. At 2:30 pm the barometer began to rise and the wind returned with increased violence, coming now from the south. During the 2nd half of the storm, and practically coinciding with the beginning of the South wind there was a sort of bore or tidal wave, caused perhaps, by the wind driving the sea into the 'Petit Cul de Sao,' and into the harbor. This wave caused considerable damage and killed many. The water rose from 10 to 12 feet above high-water mark and came into the city, bringing with it boats, barges, etc., which it left high and dry far from the wharf. Luckily the water receded almost immediately as it came in. We were unable to record either wind velocity or rainfall. The wind is estimated to have reached over 150 miles per hour and to have blown with hurricane force for about 16 hours" (NCDC - Station Agronomique de la Guadeloupe). "At 6:30 A.M. storm wind from NE ~25-30 mph, very low barometer 29.731. Storm increasing to hurricane in the day" (Leeward Islands Government Gazette – St. John's Antigua – provided by Mike Chenoweth). "At the Saintes, tiny islands about 22 miles southwest of Pointe a Pitre, the director of a bacteriological laboratory recorded a reading of 27.45 [930 mb]" (Kleinberg).

September 13: HWM analyzes a closed low of at most 995 mb centered near 17.1N, 65.2W. HURDAT listed this as a 135 kt hurricane at 17.4N, 64.7W. Ship highlights: 70 kt N and 989 mb at 20 UTC at 18.2N, 67.2W (NCDC); 931 mb in eye at 15 UTC at 17.6N, 65.2W (MWR); 70 kt ENE and 990 mb at 17 UTC at 18.3N, 64.9W (MWR). Land highlights: 139 kt NE and 976 mb at 18 UTC at San Juan, Puerto Rico at 18.5N, 66.0W (MWR); 936 mb at 1830 UTC at Guayama, Puerto Rico (MWR). "About 11 am of the 13th the hurricane center passed near the S.S. Matura, in latitude 17.6N, longitude 65.2W, a short distance southwest of St. Croix, Virgin Islands, a barograph trace received by mail showing a minimum pressure of about 27.50 inches [931 mb]. A wind velocity of 90 mph was reported from St. Thomas, 50 miles north of the center, and the island of St. Croix suffered heavily in loss of life and in damage to property and crops. The hurricane crossed Puerto Rico during the 13th, causing the loss of many lives and widespread destruction to crops and property" (MWR). "The storm broke over the southeastern portion of the island early Thursday morning with the center near Guayama and passed across the island in a west-northwest direction, leaving between Aguadilla and Isabela. The storm center moved across the island in about 8 hours at the rate of 13 mph. The barometer as the center passed to the south of San Juan at 2:30 pm, registered the very low reading of 976 mb. At Humacao on the east coast of Puerto Rico a reading of [949 mb] was recorded at 1:50 pm. Ponce reported 957 mb at 4:30 pm; Arecibo on the north coast 974 mb at 3:30 pm; Isabela on the northwest coast 941 mb at 9 pm; Mayaguez on the west coast 968 mb at 8 pm. Guayama on the southeast coast reported the lowest barometer 936 mb at 2:30 pm" (MWR). "At 11:44 am of the 13th the anemometer at the office of the United States Weather Bureau in San Juan lost one of the cups- just after recording a maximum velocity (the greatest velocity in 5 minutes) of 150 mph, and an extreme velocity (the highest velocity in 1 minute) of 160 miles. San Juan was about 30 miles from the storm center when these

velocities were recorded. Estimated winds of 200 mph near the center of the storm appear to be not much overdrawn. At San Juan the storm increased in intensity for 3 hours after the record of 150 miles (5 minutes) was made. Most of the damage to property on the Weather Bureau Reservations occurred between 2:30 and 3:30 pm. With only 2 cups the anemometer still recorded about 75 mph. The second cup disappeared at 12:47 pm. The arms and shaft of the anemometer with one cup still attached were blown away at 1:33 pm; these parts were later found a third of a mile to the southwest. The 3-cup anemometer in service at San Juan during the recent storm registers 30 per cent less than the 4-cup variety at velocities in excess of 100 mph. In other words, the 4-cup anemometer formerly used at the Weather Bureau stations would have registered not less than 190 miles (5 minutes) at San Juan on the 13th at the time the anemometer lost one cup" (MWR). "Loss of life (in Puerto Rico) will not exceed 300, due mostly to the fact that the approach of the storm was announced in time to take necessary precautions against loss of life" (MWR). "The lowest barometer at St. Thomas, Virgin Islands, 50 miles north of the path, was 992 mb with a maximum velocity of 90 mph at 10 am" (MWR). "Guayama, on the southeast coast of Porto Rico, was in the vortex of the storm at 2:30 pm of the 13th. Winds of hurricane force prevailed from 4 am to 10 pm, a period of 18 hours - assuming a progressive movement of 13 mph for the storm, the area of winds of hurricane force east to west, would be 234 miles. At San Juan, 30 miles to the north of the vortex, hurricane winds prevailed from 4 am to 4 pm, or 12 hours. Winds of hurricane force were experienced throughout the island to the north of the path (right side); to the south (left side) some portions of the coast were apparently free from hurricane winds. In spite of the great intensity and great extent of the storm no reports of loss of vessels in the vicinity of Porto Rico have been reported" (MWR). "Several hundred thousand people were rendered homeless. Some towns near the center of the storm were practically leveled. Property

and crop losses are estimated at approximately \$50,000,000" (MWR). San Juan was given 36 hours notice when storm warnings were first issued (MWR). "Eye was 15-20 miles diameter and moved WNW at 9 kt- entered Guayama - Arroyo area at 13/1830 UTC and left Aguadilla at 14/0200 UTC (7 hours and 30 minutes)...The central calm passed over Aibonito, Cayey, Adjuntas" (Perez). "A careful study of all of our records for the storm of Sept. 13th shows clearly that the path of the storm was north of Mayaguez. The barometer at Isabela on the northwest coast was 941 mb and other readings to the north of Mayaguez show lower readings than observed at Mayaguez. Several reporters state that there was an area of comparative calm between 8 and 9 pm and that the NE wind prevailing earlier changed suddenly to the SE after the passage of the lowest barometer, (at 8:10 pm). Aside from the notation of an east wind at 9 pm in the log of the Montoso, we have no evidence of the wind changing from N to S via E" (NCDC - US Dept. of Agriculture - Weather Bureau - San Juan, Puerto Rico). "At 7 A.M. hurricane abated, wind still very high, bar. 29.799, rainfall 7.31, thermometers smashed and no other readings taken" (Leeward Islands Government Gazette – St. John's Antigua – provided by Mike Chenoweth).

September 14: HWM analyzes a closed low of at most 1000 mb centered near 18.9N, 68.4W. HURDAT listed this as a 135 kt hurricane at 19.6N, 69.1W. The MWR Tracks for Centers of Cyclones shows a center near 19.3N, 68W. Ship highlights: 70 kt ENE and 970 mb at 00 UTC at 18.2N, 67.2W (NCDC); 70 kt S and 980 mb at 04 UTC at 18.2N, 67.2W (NCDC); 70 kt SSW and 992 mb at 08 UTC at 18.2N, 67.2W; 70 kt E at 12 UTC at 20.3N, 67.4W (COA). Land highlights: 941 mb (eye) at 01 UTC at Isabela, Puerto Rico at 18.5N, 67.0W (MWR); 70 kt N and 970 mb at 00 UTC at Mayaguez, Puerto Rico at 18.2N, 67.2W (NCDC); 5 kt E and 971 mb at 01 UTC at Mayaguez, Puerto Rico at 18.2N, 67.2W (NCDC); 70 kt SSE and 975 mb at 03 UTC at Mayaguez,

Puerto Rico at 18.2N, 67.2W (NCDC); 70 kt S and 980 mb at 04 UTC at Mayaguez, Puerto Rico at 18.2N, 67.2W (NCDC). The wind remained at least 70 kt S at Mayaguez until past 07 UTC, at which time the pressure rose to 991 mb. "After leaving Puerto Rico, the direction of movement of the hurricane changed from west-northwest to nearly northwest, maintaining the latter course continuously at a rate of about 14.5 miles per hour until after it passed inland over the east Florida coast near West Palm Beach. There was little damage in the island of Haiti, although the center moved near, and almost parallel to, the northeast coast" (MWR). "On the morning of the 14th, the hurricane was central off the northeastern coast of Haiti" (MWR).

September 15: HWM analyzes a closed low of 965 mb central pressure centered near 20.5N, 73.2W. HURDAT listed this as a 135 kt hurricane at 22.2N, 72.7W. The MWR Tracks for Centers of Cyclones shows a center near 22N, 72.5W. Ship highlights: 90 kt NNE at 20 UTC at 23.2N, 74.2W (MWR); 90 kt SSE at 2010 UTC at 23.2N, 74.2W (MWR); 0 kt (EYE) and 941 mb at 20 UTC at 23.2N, 74.2W (MWR); 70 kt E and 984 mb at 23 UTC at 24.2N, 74.0W (NCDC). Land highlights: 104 kt NE and 965 mb at 05 UTC at Grand Turk Island at 21.5N, 71.1W (MWR). "At midnight [~4 to 5 UTC] the barometer at Grand Turk read 28.50 inches and the wind was 120 mph from the northeast. "The center apparently passed about 9 miles south of our island, which is Grand Turk" (MWR). Regarding the ship mentioned in this day's ship highlights for 3 observations at 23.2N, 74.2W: "The German steamer August Leonhardt ... was hove to in latitude 23 deg 10 min W., longitude 74 deg 10 min W, when the center of the hurricane passed over it about 3 p. m. of the 15<sup>th</sup>, the lowest barometer reading being 27.80 inches. Just previous to the arrival of the center the wind was north-northeast force 12 (and more). After the barometer had remained stationary and the wind had calmed down for a short time, the hurricane started again at

3:10 p. m., this time blowing from the south-southeast ... 'The force of the wind, if more or less, could only be judged by the noise made by the storm, which reminded me of the New York subway going full speed passing switches. Rain and spray were carried away horizontally and our whistle started to blow loudly due to the force of wind pressing the wire. The foam and spray went up to the masthead (40 meters above the water), this being proved by our antenna and insulators which we had to take down in order to clean the salt. Hatch tarpaulins, boat ventilators, covers, etc., were torn to pieces and carried away. Spray, rain, and foam were so dense that we could not see our forecastle head'" (MWR).

September 16: HWM analyzes a closed low of at most 1000 mb centered near 25.9N, 80.2W. HURDAT listed this as a 135 kt hurricane at 25.1N, 77.2W. The MWR Tracks for Centers of Cyclones shows a center near 25.4N, 77.7W. Ship highlights: 70 kt WNW and 976 mb at 18 UTC at 25.8N, 79.7W (NCDC); 70 kt ESE and 982 mb at 00 UTC at 24.2N, 74.0W (NCDC); 70 kt WSW and 983 mb at 21 UTC at 25.7N, 79.8W (NCDC). Land highlights: 83 kt at 0830 UTC at Nassau, Bahamas at 25.0N, 77.5W (MWR/NCDC); SW wind and 951 mb at 10 UTC at Nassau, Bahamas at 25.0N, 77.5W (MWR/NCDC); 938 mb at 23 UTC at West Palm Beach, FL at 26.7N, 80.1W (MWR); 68 kt (1 min) SW at 2308 UTC at Miami, FL at 26.0N, 80.2W (OMR); 981 mb at 2215 UTC at Miami (min pressure for Miami) at 26.0N, 80.2W (OMR). "Continuing on a practically straight course from Porto Rico to Lake Okeechobee, Fla., the center of the hurricane passed near but slightly north of Nassau, Bahamas, on the morning of the 16th" (MWR). "110 to 120 mph SW and 28.08 inches at 5 am" [at Nassau, after anemometer was disabled] (MWR). "Although considerable damage was done to property and a lesser extent to crops, no loss of life occurred" (MWR). "The center of the hurricane reached the coast in the Palm Beach section about

7:00 pm of the 16th. The corrected sea-level reading is 27.43 inches, 0.18 inch lower than at Miami during the hurricane of September 18, 1926, and is the lowest pressure ever recorded in the United States during a hurricane" (MWR). Key West: "The violent tropical disturbance the center of which, moving from southeastward, impinged on the southeast coast of Florida near West Palm Beach about 6 pm, on the 16th, did not affect this station materially" (OMR). Miami: "A tropical storm of great intensity moving northwestward off the lower east coast of Florida, caused strong northwest winds during the forenoon, increasing to whole gale force during the afternoon. The wind shifted from northwest to southwest shortly after 5 pm and to south between 10 pm and 11 pm. Rain occurred at intervals during the first half of the 16th, and it was continuous after 11:40 am" (OMR).

September 17: HWM analyzes a closed low of at most 990 mb centered near 27.7N, 81.8W, or over the very central part of Florida. HURDAT listed this as a 110 kt hurricane at 27.8N, 81.5W. At 00 UTC, the MWR Tracks for Centers of Cyclones showed a center near 26.8N, 80.4W with a 929 mb pressure. At 12 UTC, the MWR Tracks for Centers of Cyclones showed a center near 28.4N, 81.8W with a 966 mb pressure. Ship highlights: 70 kt SSE at 12 UTC at 26.3N, 79.7W (COA); 979 mb with ENE wind at 04 UTC at 30.5N, 80.5W (MWR); 60 kt SW, then S and 991 mb at 00 UTC at 25.7N, 79.8W (NCDC). Land highlights: 929 mb at 00 UTC at West Palm Beach, FL at 26.7N, 80.1W; 66 kt NW and 957 mb at 0115 UTC, and Calm (EYE) and 942 mb at 0245 UTC at Canal Point, FL at 26.9N, 80.6W (MWR). "The hurricane moved northwestward over the Florida peninsula, its center passing over Lake Okeechobee during the early night of the 16th and near and slightly east of Bartow about 7 am of the 17th. Its course changed to north-northwest after leaving the Bartow section..." (MWR). "The hurricane apparently reached Lake

Okeechobee with little diminution in intensity. Complete barometric and wind data during the storm were furnished by Mr. B. A. Bourne of Plant Industry's sugar cane breeding station located on the shore of Lake Okeechobee about one-half mile northward from Canal Point. At 5 pm (16th) the barometer was 29.17 inches and the wind 40 mph from the north; at 7:48 pm (16th), the barometer was 28.54 inches and the wind 60 mph from the NW; and at 8:15 pm the anemometer cups blew away after the velocity reached 75 mph from the NW, the barometer at this time reading 28.25 inches. By 9 pm the barometer had fallen to 27.87 inches with an estimated wind velocity of 150 mph from the NW. There was a dead calm between 9:30 and 10:00 pm when the center passed over the station, the lowest barometer reading being 27.82 inches (942 mb) at 9:45 pm (0245 UTC). Shortly after 10 pm, the barometer began to rise and the wind immediately came with hurricane force from the southeast, reaching an estimated velocity of 160 mph about 10:45 pm. The wind force decreased rapidly after 11 pm" (MWR). Miami, FL: "Strong winds, reaching whole gale force at times, continued throughout the day in connections with the tropical storm of the 16th, which passed inland a short distance south of Palm Beach" (OMR). Apalachicola, FL: "A tropical hurricane which recurved to the northeastward some 150 miles to the eastward..." (OMR). "Sep. 17, 935 mb central pressure at landfall in Florida, observed at West Palm Beach Everglades Drainage District Office, 28 nm RMW, 13 kt translational velocity, landfall point 26.7N 80.0W" (Ho et al.). "111 kt 1-min max wind equivalent at landfall, 1007 mb environmental pressure" (Schwerdt et al.). "SE FL4, NE FL2, GA1, SC1, central pressure at landfall 929 mb" (Jarrell et al.) "1928, Sept. 16-17, Entire peninsula, Extreme, 1,836 killed, damage \$25,000,000" (Dunn and Miller).

September 18: HWM analyzes a closed low of at most 980 mb centered near 31N, 81.1W, or just off the coast of southern Georgia. HURDAT listed this as a 60 kt tropical storm at 32.5N, 80.8W. At 00 UTC, the MWR Tracks for Centers of Cyclones shows a center near 30.4N, 82W with a 979 mb pressure. At 12 UTC, the MWR Tracks for Centers of Cyclones shows a center near 32.2N, 81W with a 979 mb pressure. Ship highlights: 70 kt SSW and 981 mb at 11 UTC at 31.8N, 79.8W (MWR); 70 kt SSW and 982 mb at 12 UTC at 31.8N, 79.8W (COA); 60 kt and 980 mb at 07 UTC at 30.4N, 81.6W (MWR). Land highlights: 979 mb at 0730 UTC and 17 kt NW and 979 mb at 0750 UTC at Jacksonville at 30.4N, 81.7W (OMR); 26 kt N and 979 mb at 13 UTC at Savannah at 32.1N 81.2W (OMR); 23 kt SE and 980 mb at 21 UTC and 70 kt E (1 min) (no time) at Charleston at 32.8N 79.9W (OMR). "...and after passing between Ocala and Cedar Keys it turned toward the north-northeast, passing a short distance west of Jacksonville about 1 am of the 18th" (MWR). "The damage at Miami was negligible...Hollywood and Fort Lauderdale escaped with only slight structural damage to buildings...From Pompano north to Jupiter, especially at Delray, Lake Worth, Palm Beach, West Palm Beach, and Kelsey City, there was serious structural and water damage, the losses being greatest at Palm Beach and West Palm Beach... In the Lake Okeechobee region, the great loss of life and damage to property were caused by the overflowing of the lake along the southeast shore, principally at Belle Glade, Pahokee, and South Bay. The small houses in those localities were washed away or inundated, and approximately 2,000 persons were drowned" (MWR). "One of the noteworthy features in connection with the storm was the absence of serious structural damage to substantial buildings. This was also the particularly noticeable after the Miami hurricane of 1926. These two hurricanes, both of major intensity, have shown that buildings properly constructed will not suffer serious structural damage from hurricanes, and that the use of storm shutters will prevent practically any damage to such buildings. This statement to

frame buildings as well as to those constructed of steel, concrete, brick, or stone" (MWR). "The hurricane center was of great diameter... 25 miles or more (twice as large as the center of the Miami hurricane of 1926)" (MWR). The total property loss in Florida is given at \$25,000,000 (MWR). "On October 28, Red Cross officials announced their official casualty estimate, placing the number of dead at 1,836 and injured at 1,870 for the entire storm area in Florida. The detailed casualty list is as follows: West Palm Beach area (from Jupiter to Delray Beach), 26 dead, 1,437 injured; Broward County, one dead, 51 injured; Palm Beach County, 1,700 dead 266 injured; Okeechobee County, 25 dead, none injured; other territory, 84 dead, 67 injured. A total of 10,172 families had registered with the Red Cross applying for aid up to October 28, about two-thirds of this number being in Palm Beach County" (MWR). Atlanta, GA: "29.64 inches occurred on the 18th in connection with the passage of the tropical hurricane up the Georgia coast on that date. No high winds of any consequence attended the passage of this storm at Atlanta, the maximum velocity being 24 miles an hour from the northwest, and the rainfall was negligible" (OMR). Savannah, GA: "The outstanding feature of the weather for the month was the passage of a tropical storm almost over the station on the 18<sup>th</sup>...Increasing NE and E winds reached 44 miles by midnight (18th) and 48 by 3:40 am of the 18th. Steadily falling barometer during the 17th and to 8 am [13 UTC] of the 18th when it stood at 979 mb. The center of the storm was then evidently a short distance east of the station. The wind had changed to N at 7 am and lulled somewhat, but by 8:30 am it changed to NW and increased to 40 miles or more and maintained a velocity between 40 and 50 to about 2:30 am of the 19th. The heavy rain continued to the time of the passage of the center, then lighter to about 9:30 pm of the 18th, reaching the unprecedented total of 11.68 inches for the entire storm. There was no loss of life here and buildings escaped with little damage except some broken windows, but low-lying sections were flooded and roads were badly washed, trees

uprooted or broken, and telephone and telegraph wires laid low in all directions" (OMR).

Charleston, SC: "Precipitation on the 18th was extremely heavy, breaking the record at this station for 15 minutes and equaling the ten-minute record. The tropical storm which struck Florida on the 16th passed over this station on the 18th. The winds attained a great velocity during the early morning hours, reaching a maximum of 59 mi. per hour [5 min] at 4:22 am [0922 UTC]. Many trees were uprooted and some small boats were damaged but no one was injured. The sea-level pressure at 4 pm (980 mb) was the lowest since October, 1893" (OMR). Columbia, SC: "Record breaking rains of the 17th-18th attended the tropical storm passing northeastward along the Carolina coast. The high winds of the 18th prostrated about 1,000 fine large shade trees in the city, and these had to be cut and removed. Estimated at \$100 per tree, which is a low value for such trees, the general loss approximated \$100,000. The trees tilted slowly with each passing squall, and the property damage of consequence was due to the pounding of tree trunks against houses" (OMR). Charlotte, NC: "The rainfall of 5.16 inches on the 17th-18th was the greatest 24-hour fall in any month during the past 50 years. Practically no wind damage occurred in Charlotte, but there was considerable minor flooding of cellars and low places" (OMR). "The 'Okeechobee' hurricane of 1928 [death toll] be raised from 1836 to 2500 (with an asterisk denoting it could be as high as 3000)" (Pfof 2003).

September 19: HWM analyzes a closed low of at most 995 mb centered near 35.2N, 76.7W, or on the mainland coast of North Carolina with a stationary front draped on the northern side of the cyclone. HURDAT listed this as a 40 kt tropical storm at 35.8N, 77.0W. At 00 UTC, the MWR Tracks for Centers of Cyclones showed a center near 33.4N, 79.2W with a 985 mb pressure. At 12 UTC, the MWR Tracks for Centers of Cyclones showed a centered near 35.2N, 77.5W with a 994

mb pressure. Ship highlights: 5 kt SE and 986 mb at 00 UTC at 33.0N, 78.5W (COA); 60 kt NW and 991 mb at 00 UTC at 31.3N, 80.1W (COA); 60 kt S and 996 mb at 00 UTC at 32.7N, 76.0W (COA). Land highlights: 66 kt (1 min) NE at 12 UTC at Atlantic City, NJ at 39.4N, 74.5W (MWR); 63 kt NE (1 min) at Cape Henry, VA at 36.9N, 76.0W (Roth and Cobb 2001); 28 kt NW and 986 mb at 00 UTC at Charleston, SC at 32.8N, 80.0W (OMR). "After leaving Florida the storm decreased steadily in intensity as it moved close to the Georgia and South Carolina coasts and passed into North Carolina the night of the 18th-19th. On the 19th its course again changed to north and later north-northwest, diminishing greatly in intensity and merging with another disturbance over Ontario during the 20th" (MWR). Regarding the flooding in the southeast US: "By the time the hurricane crossed into the sandhills of North Carolina on the night of September 18, its destructive winds had diminished, but tremendous rains fell across the Tar Heel state. The resulting floods were very severe and the highest on record for some upper portions of the Cape Fear River. At Fayetteville, where the bank-full stage is 35 feet, the river reached an unprecedented height of 64.7 feet. At Elizabethtown, the river rose to 41.3 feet. Flooding at Lumberton was reported as 'the worst in history,' and thousands of acres of crop lands were underwater. Many highways were closed because of bridge washouts and deep-standing water" (Barnes). "Tides peaked at 7.2 feet above mean lower low water at Norfolk" (Roth and Cobb). Raleigh, NC: "The month's greatest amount of precipitation in 24 hours, 3.45 inches on the 18th and 19th, sets a new record for September... whereas there was a pressure of 995 mb recorded on September 19 (11 UTC)" (OMR). Norfolk, VA: "The storm of the 18th-19th was accompanied by severe gales. The tropical storm that was central over eastern North Carolina on the morning of September 19th, moved north-northwestward and passed west of Richmond during the night. Northeast winds of gale force began during the afternoon of September 18th and continued until

3:00 am of the 19th, causing an unusually high tide and considerable crop damage. Property damage was mostly of minor character. Many small trees were blown down, cellars flooded, traffic delayed, telephones put out of commission and electric lights cut off in parts of the city" (OMR). Baltimore, MD: "A northeast gale between 10 am and 7 pm. Maximum velocity of 47 miles from the northeast, beginning 12:18 pm. Locally some trees were uprooted and one house was unroofed. One man was killed when an uprooted tree fell on him. Some telephones were put out of order by breaking of wires. On the eastern shore, many telephones were put out of order when wires gave way under uprooted trees. Considerable corn was flattened by the gale and fruit blown off trees. There was no general property damage from the gale in Md. & Del. An unusually high tide resulted along the western shore of Chesapeake Bay" (OMR). Nantucket, MA: "Northeast storm of marked intensity began 2:35 am ( 48 mph NE 11:03 am ) and continued all day, and ended at 2:03 am the 20th. Storm was accompanied by excessive rain (3.70 inches in 24 hours). Whole gale warnings displayed from 9:30 am the 19th to 9:30 am the 20th" (OMR).

September 20: HWM analyzes a closed low of at most 1010 mb centered near 41N, 79.4W, or over western Pennsylvania, attached to the west end of a WNW-ESE warm front. HURDAT listed this as a 35 kt extratropical low at 42.0N, 78.4W. At 00 UTC, the MWR Tracks for Centers of Cyclones showed a center near 37.4N, 78.1W with an 1001 mb pressure. At 12 UTC, the MWR Tracks for Centers of Cyclones showed a center near 41.2N, 79W with an 1008 mb pressure. Ship highlights: 35 kt E and 1009 mb at 03 UTC at 38.4N, 74.3W (MWR); 35 kt NE and 1012 mb at 39.5N, 74.0W (COA). No other gales. No low pressures. Land highlights: 35 kt E at 01 UTC at Richmond, VA at 37.6N, 77.5W (OMR); 8 kt N and 1001 mb at 00 UTC at Richmond, VA at 37.6N, 77.5W (OMR); 21 kt S and 1005 mb at 00 UTC at Norfolk, VA at 36.8N, 76.5W (OMR).

No other gales. A few other low pressures. Baltimore: "During the last night northeast winds gave way to east, southeast, and south winds, which carried the unusually high tide of yesterday along the western shore of Chesapeake Bay some distance up the tributaries. In Baltimore Harbor the water this morning was so high that it covered Light Street and the floors of some piers, damaging goods stored thereon" (OMR). Nantucket, MA: "A thunderstorm of moderate energy came from the south at 1:45 am and moved toward the east through southeast, and the last thunder was heard at 3:20 am" (OMR).

Genesis is begun at 00 UTC on the 6th of September for this cyclone, 12 hours earlier than shown in HURDAT originally due to numerous ship and station observations of a well-defined closed low almost immediately off of the coast of West Africa. Only minor alterations of the cyclone's track were made, though positions every day in its 16 day existence were changed. On the 7th at 06 UTC, a peripheral pressure reading of 1003 mb suggests winds of at least 41 kt from the south of 25N Brown et al. pressure-wind relationship. Additionally, a 50 kt ship report was measured on the same date at 14 UTC. Winds are boosted to 50 kt at 12 and 18 UTC on the 7th, up from 35 kt previously. As is typical for cyclones in between the West Africa and the Caribbean, very few observations were available on the 8th and 9th. Winds were maintained at 50 kt on the 8th and 9th from continuity with the observations on the 7th, which is up from 40 kt at 12 UTC on the 8th and is no change from 12 UTC on the 9th. On the 10th at 14 UTC, the ship Clan Matheson reported 1001 mb with 50 kt of wind. This pressure suggests maximum winds of at least 45 kt from the south of 25N pressure-wind relationship. Intensity at 12 UTC on the 10th remains unchanged at 60 kt. As the cyclone continued westward late on the 10th through early on the 12th, few observations were available in the inner core of the cyclone. But given observations later on the

12th, the system undoubtedly reached hurricane strength during this period. Winds are unchanged in HURDAT on the 10th to 06 UTC on the 12th. From 1730 to 1830 UTC on the 12th, the eye of the hurricane went over Guadeloupe with calm winds at 940 mb central pressure recorded (at two separate locations on the island). This pressure suggests winds of 121 kt from the south of 25N Brown et al. pressure-wind relationship. 120 kt is chosen for HURDAT at 18 UTC on the 12th, up from 110 kt originally. This makes the cyclone a Category 4 impact in Guadeloupe, which is consistent with the extreme destruction that was caused by winds and storm surge in the island. (It is of note that Kleinberg erroneously reported a 930 mb reading at the Saintes, tiny islands about 22 miles southwest of Pointe a Pitre. Upon obtaining the original reports, the minimum pressure measured at the Saintes was in actuality 962 mb, substantially higher than that measured at Point a Pitre.)

The hurricane then turned slightly toward the west-northwest and made a direct and devastating landfall on Puerto Rico around 18 UTC on the 13th. The cyclone is known as the San Felipe hurricane in Puerto Rico. The center of the hurricane cut across Puerto Rico in about 8 hours with the “central calm” reported in Aibonito, Cayey, and Adjuntas. A possible central pressure was recorded by the ship Matura of 931 mb at 15 UTC on the 13th, just southeast of Puerto Rico. Guayama reported a minimum sea level pressure of 936 mb (and a station pressure of 931 mb). It is of note that Perez explicitly mentioned Aibonito, Cayey, and Adjuntas as experiencing the calm eye, but not Guayama. Thus it appears that Guayama may not have recorded the central pressure and 931 mb from the ship is retained as the central pressure in HURDAT at 18 UTC on the 13th and at landfall in Puerto Rico. A 931 mb central pressure suggests winds of 129 kt from the south of 25N pressure-wind relationship. The San Juan Weather Bureau office had recently replaced

their old Robinson 4-cup anemometer with the more reliable 3-cup anemometer which has a minimal bias in high winds (Fergusson and Covert 1924). This anemometer measured peak 1-min winds of 139 kt at 1544 UTC at which time the anemometer lost one of its cups. Winds were estimated by the observer to have possibly been higher than this between 1830 and 1930 UTC (at the time of the closest approach of the hurricane). An RMW value of 25 nm is quite well established between the timing of the peak estimated winds at the San Juan Weather Bureau Office at 19 UTC and landfall of the hurricane's center in southeast Puerto Rico just an hour earlier. There is no evidence that the 139 kt winds were caused by funneling between buildings or because of citing the anemometer on a tall building (J. Colon – personal communication). The observed winds, central pressure, and size of the hurricane present a dilemma, in determining its intensity. The observed winds – which appear reliable – would suggest an intensity of at least 140 kt. This would, however, be much above the pressure-wind relationship. Typically, winds can be substantially above the wind suggested by the pressure-wind relationship if the cyclone has a fast translational velocity, small RMW, and/or high environmental pressure (Knaff and Zehr 2007). This hurricane apparently had none of these three, as the hurricane was only moving at about 12 kt in its transit across Puerto Rico, had a RMW of perhaps a large 25 nmi, and was embedded in environmental pressures of about 1010 mb. We are unable here to successfully explain the discrepancy, but will go with the observed winds to estimate an intensity of 140 kt at 18 UTC on the 13th and at landfall in Puerto Rico. (One alternative possibility is that the 139 kt 1-min winds were associated with a transient mesoscale low and were not representative of the maximum winds in the eyewall of the hurricane.) This makes this hurricane – known as San Felipe in Puerto Rico – a Category 5 hurricane, which is consistent with the extreme wind caused damage across the island. No alteration to HURDAT was required at 18 UTC on the 13th, as this wind value was

already included. As the hurricane neared the northwest coast of Puerto Rico, an eye reading of 941 mb was observed in Isabella at 01 UTC on the 14th. This would suggest winds of 116 kt from Brown et al. south of 25N pressure-wind relationship for weakening cyclones. Given that the observed winds were above the pressure-wind relationship at landfall in Puerto Rico, a value of 120 kt is estimated for 00 UTC, which is a 20 kt decrease from that in HURDAT originally.

After striking Puerto Rico, the hurricane moved toward the northwest during the next three days. On the 14th, as the center of the hurricane was just north of Hispaniola, no information near the center was available. Early on the 5th, a wind observation of 104 kt NE with a concurrent 965 mb pressure was reported in Grand Turk. It appears that the center of the hurricane was about 30 nm from the island at that time, thus this pressure represents a peripheral reading, not a central pressure. Late of the 15th, a pressure of 941 mb was recorded by the ship August Leonhardt. While the ship was inside the radius of maximum wind as a distinct lull was recorded, it may not have measured the central pressure – as suggested by the peak winds only shifting from NNE to SSE bracketing the lull. This peripheral pressure suggests at least 121 kt from the south of 25N pressure-wind relationship. The original 135 kt in HURDAT is retained on the 15<sup>th</sup>. The hurricane then directly impacted the Bahamas with Nassau reporting a minimum pressure of 951 mb at 10 UTC on the 16th when the winds were blowing about 100 kt (estimated, as the anemometer was disabled earlier). Reviewing the account of the hurricane in Nassau does suggest a close bypass (winds NE-NW-SW), but without any mention of a lull. Thus the central pressure could have been close to the 929 mb central pressure at landfall in Florida. Winds of 135 kt – high end Category 4 - retained in HURDAT during passage across the Bahamas.

The hurricane next made landfall in Southeast Florida around 00 UTC on the 17th of September at 26.7N 80.0W. A 929 mb pressure reading was observed at 00 UTC on the 17th from the AT&T Company office in West Palm Beach and this is what is utilized in HURDAT and also what has been accepted as the central pressure in Jarrell et al. However, Ho et al. (and Schwerdt et al. previously) had used a 935 mb reading from the West Palm Beach Everglades Drainage District Office, as the basis for a 935 mb central pressure at landfall. Given that the pressure readings may vary based upon a true calibration as well as relative location to the exact eye center, the 929 mb value is retained as the central pressure at landfall for this hurricane. 929 mb suggests 124 kt [131 kt] from the north of 25N [south of 25N] Brown et al. pressure-wind relationship. The hurricane was rather large in size (325 nmi radius of closed isobar and RMW of 25 nmi – compared with 15 nmi from climatology for this landfall latitude and central pressure [Vickery et al. 2001]). (Ho et al. had estimated a 28 nm RMW. However, after reviewing all available observations, it appears that this was somewhat too large. Our best estimate of the RMW is 25 nm, plus/minus 5 nm.) The environmental pressures were somewhat low, with an outer closed isobar of 1009 mb. The translational velocity was moderate at about 13 kt at landfall. Taking an average of the pressure-wind relationship for south and north of 25N gives 128 kt. Accounting for the large size and low environmental pressures would indicate a maximum 1-min wind of about 125 kt at landfall in southeast Florida, making this a US Category 4 hurricane. This is a 5 kt reduction from what was in HURDAT originally. Peak observed winds after landfall were 60 kt within 2 hr of 06 UTC on the 17th, 70 kt at 12 UTC, and 42 kt at 18 UTC, though the available observations were extremely sparse (the 60 and 70 kt reports were actually ship reports though the hurricane was overland). A run of the Kaplan and DeMaria inland-decay model suggests winds of 74 kt at 06 UTC, 58 kt at 12 UTC, and 48 kt at 18 UTC. Because of the large size of the hurricane and that it was likely

intensifying right up until landfall, winds are chosen for HURDAT after landfall substantially higher than the inland-decay model would suggest: 100 kt at 06 UTC, 85 kt at 12 UTC, and 75 kt at 18 UTC. These values are reduced from that originally shown in HURDAT by 15, 25, and 15 kt, respectively. Based upon these analyzed winds, SW Florida was impacted by Category 3 hurricane winds and NW Florida was impacted by Category 1 hurricane winds. Neither region was included in the hurricane state impact summary in HURDAT previously. The hurricane recurved over the Florida peninsula late on the 17th and early on the 18th and the center passed just east of Jacksonville. Jacksonville's 17 kt NW concurrent with 979 mb minimum pressure at 0750 UTC on the 18th suggests a central pressure of 977 mb (which is now included into HURDAT at 06 UTC). This central pressure suggests winds of 76 kt from the north of 25N pressure-wind relationship (73 kt for filling cyclones). Given that the maximum winds were still over land at 06 UTC, the intensity at this time analyzed to be 65 kt, down from 75 kt originally. (It is noted that pressures were estimated every 12 hours into HURDAT after landfall [955 mb at 12 UTC on the 17th, 974 mb at 00 UTC on the 18th, etc.]. However, none of these are based upon any direct observations as can be determined. These are now removed from HURDAT.)

The hurricane made oceanfall around 08 UTC on the 18th back over the Atlantic Ocean. Savannah measured 26 kt N winds with 979 mb pressure at 13 UTC on the 18th. This suggests a central pressure of 976 mb as the hurricane passed just east of the city, which supports winds of 77 kt from the north of 25N pressure-wind relationship. Winds are chosen to be 75 kt in HURDAT at 12 UTC, up from 60 kt originally. The hurricane made a second mainland US landfall near 32.5N 80.3W in southern South Carolina around 19 UTC on the 18th. Charleston reported 23 kt SE wind with 980 mb at 21Z, suggesting about 977 mb central pressure at that time. Peak observed 1-min

winds were 70 E kt at Charleston. Maximum 1-min winds at landfall are estimated to have been 75 kt, making this a Category 1 hurricane for South Carolina. As the revised track was slightly offshore of Georgia, the maximum winds would not have impacted the Georgia coast. However, it is likely that minimal hurricane force 1-min winds (~65 kt) impacted parts of the Georgia coastline. Thus Georgia is retained in HURDAT as a Category 1 impact. Peak observed winds after landfall were the following: 60 kt at 00 UTC on the 19th, 56 kt at 06 UTC, 66 kt at 12 UTC, and 50 kt at 18 UTC. The cyclone was undergoing extratropical transition on the 19th and is analyzed to have become extratropical at 12 UTC on the 19th, 24 hours earlier than identified previously. The system reintensified briefly as an extratropical storm based upon hurricane force winds observed in Atlantic City and close to hurricane force in Cape Henry. Winds are analyzed to be 65 kt at 00 UTC on the 19th (up from 50 kt originally), 60 kt at 06 UTC (up from 45 kt), 70 kt at 12 UTC (up from 40 kt), and 60 kt at 18 UTC (up from 40 kt). Gradual weakening occurred after 12 UTC on the 19th as an extratropical storm. The last entry in HURDAT before dissipation is 00 UTC on the 21st, six hours later than originally in HURDAT.

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Storm #4, 1928 (The San Felipe/Lake Okeechobee Hurricane) NHC Best Track Change

Committee Comments and Replies to the Comments

Comments on the proposed revisions to the 1928 Hurricane Season from the Best Track

Supervisory Committee are in regular font. **[Replies to the Committee are indented and**

**boldface. – Chris Landsea – June 2010]**

Storm #4, 1928:

1. The 50 kt observation on 7 September is a south wind (presumably east of the center), which suggest the possibility that the winds were stronger north of the center. Please consider revising the intensities for this and subsequent days.

**[Agreed.]**

2. Does the available data justify the small kinks shown in the track on 12 and 14 September (especially the one that brought the center close to the north coast of Hispaniola?) If not, please consider smoothing the kinks out.

**[Observations do confirm a modest turn of the hurricane toward the west-northwest beginning around 00 UTC 13<sup>th</sup>. Agreed to smooth the kink around 12 UTC on the 14<sup>th</sup>, as there is limited inner core data.]**

3. Is the discussion of the storm rainfall in the 14 September daily description relevant? If not, please remove it. The same applies to the other descriptions of rain and flooding caused by this system. They are relevant to the storm impacts, but they are not relevant to the best track or revising it.

**[Agreed to remove.]**

4. In the metadata summary, the sea level pressure in the “calm” eye at Guayama was 936 mb, yet in the next sentence there is an assumption that Guayama may not have recorded the central pressure. How calm was the eye at Guayama? The same issue is apparent with the ship report used for the central pressure on 15 September. The account of the wind shift from north-northeast to south-southeast suggests that the ship was not in the geometrical center of the eye, yet

the 941 mb is accepted as the central pressure. How calm was the eye over the ship? Please resolve this apparent contradiction.

**[Upon further investigation, it appears likely that Guayama was not in the calm eye. Guayama did report a minimum sea level pressure of 936 mb, but Perez' Puerto Rico hurricane history documentation lists only Aibonito, Cayey, and Adjuntas as experiencing the "central calm". Thus it appears likely that Guayama did not record the central pressure. This is now clarified.]**

**For the ship observation on the 15<sup>th</sup>, MWR had the following information: "The German steamer August Leonhardt ... was hove to in latitude 23 deg 10 min W., longitude 74 deg 10 min W, when the center of the hurricane passed over it about 3 p. m. of the 15<sup>th</sup>, the lowest barometer reading being 27.80 inches. Just previous to the arrival of the center the wind was north-northeast force 12 (and more). After the barometer had remained stationary and the wind had calmed down for a short time, the hurricane started again at 3:10 p. m., this time blowing from the south-southeast". Thus while the ship was inside the radius of maximum wind, it may not have measured the central pressure – as suggested by the peak winds only shifting from NNE to SSE. The original 135 kt in HURDAT is retained on the 15<sup>th</sup>.]**

5. The metadata summary section describes the difficulties in resolving the intensity of the hurricane over Puerto Rico. How certain is the 25 n mi radius of maximum winds? The description of the eye passage over Guadeloupe suggests the eye lasted about an hour, which from the forward speed suggests the eye was about 13 n mi in diameter. This would produce a smaller

RMW than 25 n mi. Is there any other potential evidence that the hurricane underwent an eyewall replacement between Guadeloupe and Puerto Rico?

**[An RMW value of 25 nm is quite well established between the timing of the peak estimated winds at the San Juan Weather Bureau Office at 19 UTC and landfall of the hurricane's center in southeast Puerto Rico just an hour earlier. The change in character of the hurricane between its passage over Guadeloupe and over Puerto Rico is consistent with an eyewall replacement.]**

6. The committee has some issues with the intensity over the Bahamas. First, the 15 September daily section mentions that the center passed about 9 miles south of Grand Turk. How far is Grand Turk from the proposed track? If it was 9 miles from the center, then Grand Turk was likely inside the RMW and the 965 mb pressure suggests a rise in the central pressure after the hurricane left Puerto Rico. If Grand Turk was not inside the RMW, the central pressure could have been considerably lower than 965 mb.

**[The passage of the hurricane 9 miles south of Grand Turk estimated by the observer was likely incorrect. Instead, our distance at the time of the minimum pressure was about 30 nm. Thus the 965 mb pressure value is likely a peripheral one, not a central pressure. As discussed earlier, also on the 15<sup>th</sup>, a ship had a peripheral pressure of 941 mb, so the 965 mb is likely much larger than the true central pressure.]**

Second, the same arguments can be made for the Nassau observation. How far was it from the center and was it inside the RMW? If it was inside the RMW, then the 951 mb pressure and the estimated winds suggest a pressure close to the 941 mb ship report. If it was not inside the

RMW, then the central pressure could have been considerably lower. Note that the Monthly Weather Review description of the hurricane at Nassau does not include anything that looks like an eye passage.

Please clarify these issues if possible and adjust the intensity if necessary.

**[Reviewing the account of the hurricane in Nassau does suggest a close bypass (winds NE-NW-SW), but without any mention of a lull. Thus the central pressure could have been close to the 929 mb central pressure at landfall in Florida. Winds of 135 kt – high end Category 4 - retained in HURDAT during passage across the Bahamas.]**

7. Please state the basis for the 28 n mi RMW at landfall in Florida. Various accounts of this hurricane suggest the eye was anywhere from 25 to 40 miles wide, with only the larger of those supporting this RMW. The Monthly Weather Review description of the eye passage at Canal Point indicates that the strongest winds were separated from the minimum pressure by 45-60 minutes for a storm moving about 13 kt. While not conclusive, this also suggests a smaller RMW. Given the importance of the RMW in determining the landfall intensity, there needs to be more information about how the 28 n mi figure was arrived at.

**[The 28 nm RMW is provided by the Ho et al. study. Reviewing all of the data available, it is agreed that the 28 nm is somewhat too high. (Of course, unless a particular location that experiences the eye has the exact center go over it, the implied radius will be a smaller distance than the true radius.) Thus our best analysis is that the RMW was 25 nm, plus/minus 5 nm.]**

If it turns out that the RMW is smaller than 28 n mi, the committee suggests the intensity for the Florida landfall remain 130 kt.

**[Given that the hurricane's RMW is still fairly large compared to climatology, the environmental pressures were low, and the translational velocity was near average, this would still call for a modest reduction from the pressure-wind relationship. Now that the 15<sup>th</sup> and 16<sup>th</sup> intensity is retained at 135 kt, we are constrained to not use the intensifying subset of the Brown et al. pressure-wind relationship. Taking an average of the pressure-wind relationship for south and north of 25N gives 128 kt. Accounting for the large size and low environmental pressures would indicate a maximum 1-min wind of about 125 kt at landfall in southeast Florida, making this a US Category 4 hurricane. This is a 5 kt reduction from what was in HURDAT originally.]**

8. Is there any time series of data available from Jacksonville to show where the center passed in relation to that station?

**[Yes, this was already shown in the spreadsheet database and plotted previously as a time series on the 18<sup>th</sup> of September map. Based upon this, the center passed just east of Jacksonville.]**

9. While the center may have been just offshore, the new proposed track is close enough to the Georgia coast so that the left side RMW may have been onshore. Given that, is removing the GA1 status justified? Observations from Jacksonville could help resolve this as well.

**[Agreed to keep Georgia in as a Category 1 hurricane impact from this system.]**

10. In the 18 September daily section, is “26 N and 979 mb at 13 UTC at Savannah” missing a kt abbreviation?

**[Yes, corrected.]**

11. What is the relevance of the data from the Kaplan/DeMaria inland decay model for 19 September in the last paragraph of the metadata summary? The revised HURDAT does not seem to follow it, and its use during extratropical transition appears dubious. Please clarify why it is there or remove it.

**[Agreed to remove the run of the Kaplan/DeMaria model for the 19<sup>th</sup> of September.]**

## On-line Appendix References

Barnes, J., 1998: *North Carolina's Hurricane History*. University of North Carolina Press, 256 pp.

Dunn, G. E., and B. I. Miller, 1960: *Atlantic Hurricanes*. Louisiana State University Press, 326 pp.

Ho, F., P, J. C. Su, K. L. Hanevich, R. J. Smith, and F. P. Richards, 1987: Hurricane climatology for the Atlantic and Gulf coasts of the United States. NOAA Tech. Rep. NWS 38, 193 pp.

Jarrell, J. D., P. J. Hebert, and M. Mayfield, 1992: Hurricane experience levels of coastal county populations from Texas to Maine. NOAA Tech. Memo. NWS NHC-46, 152 pp.

Kleinberg, E., 2003: *Black Cloud - The Great Florida Hurricane of 1928*. Carroll & Graf Publishers, New York, 320 pp.

Perez, O., 1971: Notes on the Tropical Cyclones of Puerto Rico, 1508-1970. Unpublished manuscript available at: < [http://www.aoml.noaa.gov/hrd/data\\_sub/perez\\_1\\_10.pdf](http://www.aoml.noaa.gov/hrd/data_sub/perez_1_10.pdf) >.

Pfost, R. L., 2003: Reassessing the impact of two historical Florida hurricanes. *Bull. Amer. Meteor. Soc.*, **84**, 1367-1372.

Roth, D. M., and H. D. Cobb III, cited 2001: Virginia hurricane history.[Available online at <http://www.hpc.ncep.noaa.gov/research/roth/vahur.htm>.]

Schwerdt, R. W., F. P. Ho, and R. R. Watkins, 1979: Meteorological criteria for standard project hurricane and probable maximum hurricane windfields, Gulf and East Coasts of the United States. NOAA Tech. Rep. NWS 23, 317 pp.



Table A1: Significant (hurricane force and greater) reports collected in the database for Storm #4, 1928 (the San Felipe/Lake Okeechobee Hurricane). Note that the complete database includes all reports of gales force (34 kt) or stronger and 980 mb pressures or lower. Sources shown here are Monthly Weather Review (MWR), Comprehensive Ocean Atmosphere Dataset (COA), individual ship data provided from the National Climate Data Center (NCDC), the U.S. Weather Bureau Original Monthly Records, and additional observations provided by Mike Chenoweth and Jose Colon. Comments include eye passage, minimum pressure and maximum winds, if known.

Day	OBS	PRES	WIND	DIR	TEMP	LOCATION	LAT	LON	SOURCE	SHIP NAME/ID	COMMENTS
28 STORM 4 (SEPTEMBER)											
12-Sep	16Z	973				POINTE A' PITRE, GUAD.	162	615	MWR		
12-Sep	17Z	946				POINTE A' PITRE, GUAD.	162	615	MWR		
12-Sep	1730Z	940				AGRONOMIQUE, GUAD.	162	615	NCDC		
12-Sep	18Z	940	0			POINTE A' PITRE, GUAD.	162	615	MWR		Eye
12-Sep	18Z	940	0			AGRONOMIQUE, GUAD.	162	615	NCDC		Eye
12-Sep	1830Z	940		S		AGRONOMIQUE, GUAD.	162	615	NCDC		
12-Sep	19Z	944				POINTE A' PITRE, GUAD.	162	615	MWR		
12-Sep	20Z	964				POINTE A' PITRE, GUAD.	162	615	MWR		
12-Sep	2230Z	955				MARTINIQUE	146	611	CHEN		Min-P
13-Sep	12Z	976				SHIP	176	652	MWR	"MATURA"	
13-Sep	13Z	960				SHIP	176	652	MWR	"MATURA"	
13-Sep	13Z	1001	65	E	77	SAN JUAN	185	660	MWR		
13-Sep	14Z		78	N/A		ST. THOMAS	184	649	MWR		MAX WIND
13-Sep	14Z	1000	70	NE	77	SAN JUAN	185	660	MWR		
13-Sep	15Z	931	Calm			SHIP	176	652	MWR	"MATURA"	Eye
13-Sep	15Z	997	122	NE	78	SAN JUAN	185	660	MWR		
13-Sep	16Z	945				SHIP	176	652	MWR	"MATURA"	
13-Sep	16Z	990	130	NE	78	SAN JUAN	185	660	MWR		
13-Sep	17Z	963				SHIP	176	652	MWR	"MATURA"	
13-Sep	17Z	986	130	NE	78	SAN JUAN	185	660	MWR		
13-Sep	17Z	990	70	ENE		SHIP-"HENRY HOLMES"	183	649	MWR	UK036719	Min-P
13-Sep	1750Z	949				HUMACAO, P.R.	182	660	MWR		MIN PRESS
13-Sep	18Z	975				SHIP	176	652	MWR	"MATURA"	
13-Sep	18Z	976	139	NE	78	SAN JUAN	185	660	MWR		
13-Sep	18Z	998	70	NNE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
13-Sep	1830Z	976				SAN JUAN	185	660	MWR		MIN PRESS
13-Sep	1830Z	936				GUAYAMA, P.R.	180	662	MWR		MIN PRESS
13-Sep	19Z	980		NE	80	SAN JUAN	185	660	MWR		
13-Sep	19Z	995	70	NNE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
13-Sep	1930Z	974				ARECIBO, P.R.	185	668	MWR		MIN PRESS
13-Sep	20Z	983	96	E	78	SAN JUAN	185	660	MWR		
13-Sep	20Z	989	70	N		SHIP	182	672	NCDC	"MONTOSA"	
13-Sep	20Z	989	70	NNE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
13-Sep	2030Z	957				PONCE, P.R.	180	666	MWR		MIN PRESS
13-Sep	21Z	986	78	E	77	SAN JUAN	185	660	MWR		
13-Sep	21Z	980		N	78	HORMIGUEROS, P.R.	182	671	NCDC		
13-Sep	21Z	987	70	NNE		MAYAGUEZ	182	672	NCDC	PORTO PIER	

13-Sep	22Z	952				LARES, P.R.	183	669	COLON		MIN PRESS
13-Sep	22Z	971		NW	77	HORMIGUEROS, P.R.	182	671	NCDC		
13-Sep	22Z	977	70	N		MAYAGUEZ	182	672	NCDC	PORTO PIER	
13-Sep	23Z	965		NW	77	HORMIGUEROS, P.R.	182	671	NCDC		
13-Sep	23Z	972	70	N		MAYAGUEZ	182	672	NCDC	PORTO PIER	
13-Sep	N/A		70	E		SHIP	205	666	MWR	"PONCE"	Max-W
14-Sep	0Z	968				MAYAGUEZ	182	672	MWR		MIN PRESS
14-Sep	0Z	964			78	HORMIGUEROS, P.R.	182	671	NCDC		Min-P
14-Sep	0Z	970	70	ENE		SHIP	182	672	NCDC	"MONTOSA"	
14-Sep	0Z	970	70	N		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	0Z	964				CABO ROJO, P.R.	181	672	COLON		MIN PRESS
14-Sep	0030Z	970	50	ENE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	1Z	941				ISABELA, P.R.	185	670	MWR		Eye
14-Sep	1Z	969		S	77	HORMIGUEROS, P.R.	182	671	NCDC		
14-Sep	1Z	971	5	E		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	2Z	972		S	77	HORMIGUEROS, P.R.	182	671	NCDC		
14-Sep	2Z	973	50	SSE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	3Z	977		S	77	HORMIGUEROS, P.R.	182	671	NCDC		
14-Sep	3Z	975	70	SSE		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	4Z	980	70	S		SHIP	182	672	NCDC	"MONTOSA"	
14-Sep	4Z	980	70	S		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	5Z	983	70	S		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	6Z	986	70	S		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	7Z	991	70	S		MAYAGUEZ	182	672	NCDC	PORTO PIER	
14-Sep	8Z	992	70	SSW		SHIP	182	672	NCDC	"MONTOSA"	
14-Sep	12Z		70	E	76	SHIP	203	674	COA	US072557	
15-Sep	5Z	965	104	NE		GRAND TURK IS.	215	711	MWR		
15-Sep	17Z		70	NNE	78	SHIP	235	745	COA	2057992	
15-Sep	~20Z		90	NNE		SHIP	232	742	MWR	"AUGUST LENHARDT"	
15-Sep	20Z	941	0			SHIP	232	742	MWR	"AUGUST LENHARDT"	Eye
15-Sep	2010Z		90	SSE		SHIP	232	742	MWR	"AUGUST LENHARDT"	
15-Sep	21Z		70	SSE	80	SHIP	235	745	COA	2057992	
15-Sep	23Z	984	70	E		SHIP	242	740	NCDC	"NEVADAN"	
16-Sep	0Z	982	70	ESE		SHIP	242	740	NCDC	"NEVADAN"	
16-Sep	1Z		70	SSW	77	SHIP	235	745	COA	2057992	
16-Sep	1Z	985	70	SE		SHIP	242	739	NCDC	"NEVADAN"	
16-Sep	5Z	998	70	SSE		SHIP	241	737	NCDC	"NEVADAN"	
16-Sep	7Z	982	65	NE		NASSAU	250	775	NCDC		
16-Sep	0830Z		83			NASSAU	250	775	NCDC		
16-Sep	9Z	957		NW		NASSAU	250	775	NCDC		
16-Sep	10Z	951		SW		NASSAU	250	775	MWR/NCDC		MIN PRESS
16-Sep	11Z	965				NASSAU	250	775	NCDC		
16-Sep	17Z	989	70	N		SHIP	258	797	NCDC	"MIGUEL DE HARRINAGO"	
16-Sep	18Z	976	70	WNW		SHIP	258	797	NCDC	"MIGUEL DE HARRINAGO"	Min-P
16-Sep	20Z	980				WEST PALM BEACH	267	801	MWR		
16-Sep	21Z	970				WEST PALM BEACH	267	801	MWR		
16-Sep	21Z	983	70	WSW		SHIP	257	798	NCDC	"MIGUEL DE HARRINAGO"	
16-Sep	22Z	949				WEST PALM BEACH	267	801	MWR		
16-Sep	23Z	938				WEST PALM BEACH	267	801	MWR		
17-Sep	0Z	929				WEST PALM BEACH	267	801	MWR		Eye
17-Sep	1Z	938				WEST PALM BEACH	267	801	MWR		
17-Sep	0115Z	957	66	NW		CANAL POINT, FL	269	806	MWR		
17-Sep	2Z	944		NW		CANAL POINT, FL	269	806	MWR		
17-Sep	2Z	961				WEST PALM BEACH	267	801	MWR		
17-Sep	0245Z	942			EYE	CANAL POINT, FL	269	806	MWR		MIN PRESS
17-Sep	3Z	973				WEST PALM BEACH	267	801	MWR		
17-Sep	4Z	979		ENE		SHIP	305	805	MWR	"EL NORTE"	

17-Sep	4Z	976				WEST PALM BEACH	267	801	MWR		
17-Sep	5Z	979				WEST PALM BEACH	267	801	MWR		
17-Sep	12Z		70	SSE	80	SHIP	263	797	COA	US074534	
17-Sep	N/A	966				BARTOW	279	819	MWR		MIN PRESS
18-Sep	7Z	980	60			SHIP	304	816	MWR	"NIDARHOLM"	Min-P
18-Sep	0730Z	979			71	JACKSONVILLE	304	817	OMR	MIN PRESS	
18-Sep	0750Z	979	17	NW	71	JACKSONVILLE	304	817	OMR		
18-Sep	11Z	981	70	SSW		SHIP-"HARVESTER"	318	798	MWR	US073413	Min-P
18-Sep	12Z	982	70	SSW	74	SHIP-"HARVESTER"	318	798	COA	US073413	
18-Sep	12Z	980	26	N	68	SAVANNAH	321	812	HWM/OMR		
18-Sep	13Z	979	26	N	68	SAVANNAH	321	812	OMR		MIN PRESS
18-Sep	N/A		70	SE		SHIP	N/A	N/A	MWR	"EL NORTE"	Max-W

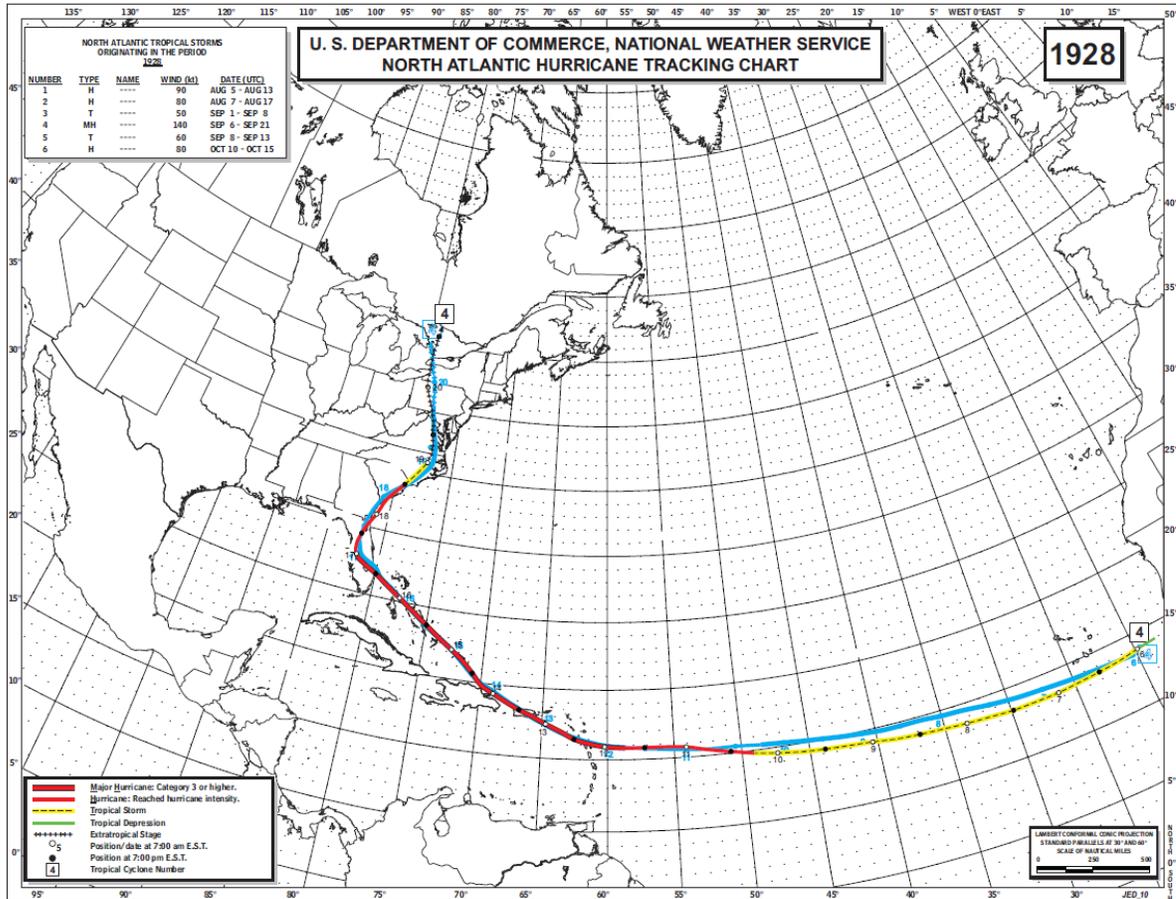


Figure 1A: The comparison (with original track in blue underlying revised track) Atlantic basin TC track map for Storm #4 – “the San Felipe/Lake Okeechobee Hurricane” in 1928.