Supplementary Material for JCLI-D-11-00420

On the Classification of Extreme Atlantic Hurricanes Utilizing Mid-Twentieth-Century Monitoring Capabilities

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APPENDIX A

Routine military aircraft reconnaissance of tropical cyclones in the Atlantic Basin began in 1944. According to the preliminary reanalysis of the 1944-1953 Atlantic hurricane seasons (Hagen et al. 2012), the tropical cyclones of that decade that were sampled one or more times by aircraft reconnaissance are listed below according to revised storm number. Most of the new tropical cyclones and all of the cyclones that stayed completely in the eastern half of the basin were not sampled, and some cyclones in the western half of the basin were not sampled as well. Most of these were short-lived tropical storms or storms that were over water for less than a day.

The list of tropical cyclones in this appendix indicates whether each cyclone was sampled one or more times by aircraft. The column on the right lists the number of TC days during the cyclone's lifetime during which there was at least one aircraft reconnaissance flight. TC days for which the cyclone was overland for all 24 hours are not included in the days column. The phrase "excluding E. Atlantic only" means that tropical cyclones who's entire lifetime occurred in the eastern Atlantic and outside the range of aircraft reconnaissance were not tallied in that metric. The phrase "extra E. Atlantic days" adds up the number of days TCs spent over the east Atlantic that eventually reached the western Atlantic. For the ten-year period of 1944-53, there was aircraft reconnaissance on 381/512 (74%) of the days during which there was a TC occurring in the western half of the basin that was listed in the original HURDAT database.

Storm (Dates)	At least 1 flight?	Days with at least 1 flight

194401 (7/13-7/18): Yes 5/6
194402 (7/24-7/28): Yes 3/5
194403 (7/30-8/4): Yes 2/3
194404 (8/16-8/24): Yes 7/9
194405 (8/18-8/23): Yes 5/5
194406 (9/10-9/11): No 0/1
194407 (9/9-9/15): Yes 6/7
194408 (9/19-9/22): Yes 3/3
194409 (9/21-9/26): No (E. Atlantic) 0/6
194410 (9/30-10/2): No (New) 0/3
194411 (9/30-10/3): Yes 2/4
194412 (10/11-10/17): No (E. Atlantic, New) 0/7
194413 (10/12-10/20): Yes 6/8
194414 (11/1-11/3): Yes (New) 1/3

1944 total: 10/14 TCs have AC (40/70)
1944 total: 9/11 original TCs have AC; 1/3 new TCs have AC (39/57)
1944 total: 9/10 original TCs excluding E. Atlantic only have AC (39/51) (1 extra E Atl day)

194501 (6/20-6/27): Yes 7/8
194502 (7/19-7/22): Yes 3/4
194503 (8/2-8/4): Yes 3/3
194504 (8/17-8/21): Yes 5/5
194505 (8/24-8/29): Yes 4/4
194506 (8/29-9/1): Yes 1/3
194507 (9/2-9/6): Yes 3/4
194508 (9/9-9/12): Yes 4/4
194509 (9/12-9/18): Yes 4/5
194510 (10/2-10/7): Yes 3/3
194511 (10/10-10/13): No 0/4

1945 tota1: 10/11 TCs have AC (37/47)
1945 total: 10/11 original TCs have AC (37/47)
1945 total: 10/11 original TCs excluding E. Atlantic only have AC (37/47) (0 extra E Atl days)

194601 (6/13-6/16): Yes 3/4
194602 (7/5-7/8): No 0/4
194603 (8/25-8/26): No 0/1
194604 (9/12-9/14): Yes 3/3
194605 (10/1-10/6): No (E Atlantic, New) 0/6
194606 (10/5-10/9): Yes 2/3
194607 (10/31-11/3): Yes 1/3
194608 (11/3): No (New) 0/1

1946 total: 4/8 TCs have AC (9/25)
1946 total: 4/6 original TCs have AC; 0/2 new TCs have AC (9/18)

1946 total: 4/6 original TCs excluding E. Atlantic only have AC (9/18) (0 extra E Atl days)

194701 (7/31-8/2): Yes	2/2
194702 (8/9-8/16): Yes	4/7
194703 (8/18-8/27): Yes	5/7
194704 (9/4-9/21): Yes	6/16
194705 (9/7-9/9): Yes	1/2
194706 (9/19-9/23): Yes	4/5
194707 (10/7-10/9): No	0/1
194708 (10/8-10/10): No (E. Atlantic, New)	0/3
194709 (10/8-10/16): Yes	6/8
194710 (10/17-10/22): Yes	6/6

1947 total: 8/10 TCs have AC (34/57)
1947 total: 8/9 original TCs have AC; 0/1 new TCs have AC (34/54)
1947 total: 8/9 original TCs excluding E. Atlantic only have AC (34/54) (7 extra E Atl days)

194801 (5/22-5/29): Yes	1/8
194802 (7/7-7/11): No	0/3
194803 (8/26-9/1): Yes	7/7
194804 (8/30-9/1): Yes	2/3
194805 (8/31-9/6): Yes	4/5
194806 (9/4-9/15): Yes	5/12
194807 (9/7-9/9): No (new)	0/3
194808 (9/18-9/24): Yes	5/7
194809 (10/3-10/16): Yes	5/14
194810 (11/8-11/11): Yes	3/4

1948 total: 8/10 TCs have AC (32/66)
1948 total: 8/9 original TCs have AC; 0/1 new TCs have AC (32/63)
1948 total: 8/9 original TCs excluding E. Atlantic only have AC (32/63) (14 extra E Atl days)

194901 (8/21-8/25): Yes	5/5
194902 (8/23-8/29): Yes	4/4
194903 (8/30-9/3): Yes	4/5
194904 (9/3-9/10): Yes	8/8
194905 (9/3-9/5): Yes	1/2
194906 (9/5-9/12): No (E. Atlantic)	0/8
194907 (9/12-9/14): No (New)	0/2
194908 (9/13-9/17): No (E. Atlantic)	0/5
194909 (9/20-9/26): Yes	7/7
194910 (9/20-9/22): Yes	3/3
194911 (9/27-10/6): Yes	2/4
194912 (10/2-10/7): Yes (New)	2/6
194913 (10/12-10/19): Yes	4/8
194914 (10/13-10/17): No	0/5

194915 (11/1-11/5): Yes (New) 2/5
194916 (11/3-11/5): Yes 2/2

1949 total: 12/16 TCs have AC (44/79)
1949 total: 10/13 original TCs have AC; 2/3 new TCs have AC (40/66)
1949 total: 10/11 original TCs excluding E. Atlantic only have AC (40/53) (3 extra E Atl days)

195001 (8/12-8/21): Yes 9/10
195002 (8/20-9/1): Yes 10/12
195003 (8/21-9/4): Yes 8/15
195004 (8/30-9/11): Yes 12/13
195005 (9/1-9/9): Yes 5/6
195006 (9/8-9/17): Yes 7/10
195007 (9/27-10/4): Yes 5/8
195008 (10/1-10/4): Yes 3/4
195009 (10/8-10/11): Yes 3/4
195010 (10/11-10/16): Yes 2/6
195011 (10/13-10/20): Yes 4/6
195012 (10/17-10/24): No (E. Atlantic) 0/8
195013 (10/18-10/22): Yes 4/4
195014 (10/25-10/28): No (E Atlantic, New) 0/4
195015 (10/27-10/29): No (E Atlantic, New) 0/3
195016 (11/10-11/12): No (New) 0/3

1950 total: 12/16 TCs have AC (72/116)
1950 total: 12/13 original TCs have AC; 0/3 new TCs have AC (72/106)
1950 total: 12/12 original TCs excluding E. Atlantic only have AC (72/98) (13 extra E Atl days)

195101 (1/4-1/9): No (New) 0/6
195102 (5/16-5/24): Yes 8/9
195103 (8/2-8/5): Yes 2/4
195104 (8/9-8/23): Yes 9/14
195105 (8/27-9/5): Yes 4/10
195106 (9/1-9/11): Yes 7/11
195107 (9/2-9/9): Yes 2/8
195108 (9/19-9/22): Yes 3/3
195109 (9/29-10/6): Yes 7/8
195110 (10/12-10/17): Yes 3/6
195111 (10/15-10/17): Yes 2/3
195112 (12/7-12/11): No (E Atlantic, New) 0/5

1951 total: 10/12 TCs have AC (47/87)
1951 total: 10/10 original TCs have AC; 0/2 new TCs have AC (47/76)
1951 total: 10/10 original TCs excluding E Atlantic only have AC (47/76) (19 extra E Atl days)

195201 (2/3-2/4): No 0/2

195202 (8/18-9/3): Yes 7/14
195203 (8/27-8/28): No (New) 0/2
195204 (8/30-9/7): Yes 7/9
195205 (9/8-9/11): No (E Atlantic, New) 0/4
195206 (9/23-9/28): Yes 3/6
195207 (9/24-9/30): Yes 5/7
195208 (9/25-9/28): No (E Atlantic, New) 0/4
195209 (10/6-10/11): Yes 3/6
195210 (10/20-10/27): Yes 7/8
195211 (11/26-11/30): Yes (New) 1/5

1952 total: 7/11 TCs have AC (33/67)
1952 total: 6/7 original TCs have AC; 1/4 new TCs have AC (32/52)
1952 total: 6/7 original TCs excluding E Atlantic only have AC (32/52) (9 extra E Atl days)

195301 (5/25-6/7): Yes 6/12
195302 (7/11-7/15): No (New) 0/4
195303 (8/11-8/15): Yes 3/5
195304 (8/28-9/1): Yes 2/5
195305 (8/28-9/8): Yes 7/11
195306 (9/8-9/12): Yes 5/5
195307 (9/10-9/11): No (E Atlantic, New) 0/2
195308 (9/15-9/18): Yes 4/4
195309 (9/15-9/21): Yes 2/6
195310 (9/23-9/27): Yes 3/4
195311 (10/2-10/12): Yes 1/11
195312 (10/3-10/6): No 0/3
195313 (10/7-10/10): Yes 3/4
195314 (11/23-11/26): Yes 2/4
195315 (12/7-12/9): Yes 1/3

1953 total: 12/15 TCs have AC (39/83)
1953 total: 12/14 original TCs have AC; 0/2 new TCs have AC (39/77)
1953 total: 12/13 original TCs excluding E Atlantic only have AC (39/77) (11 extra E Atl days)

1944-53 total: 93/123 (76%) TCs have AC
387/697 (56%) of TC days have AC
1944-53 total: 89/103 (86%) original TCs have AC; 4/21 (19%) new TCs have AC
381/616 (62%) original TC days have AC
1944-53 total: 89/98 (91%) original TCs excluding E. Atlantic only have AC
381/589 (65%) original TC days excluding E. Atlantic only have AC
381/512 (74%) original TC days excluding E. Atlantic and excluding extra E. Atlantic days have AC

APPENDIX B

1. Hurricane Mitch (1998)

The center of Hurricane Mitch (1998) passed about 10 nmi from Swan Island as a Category 5 hurricane with a 155 kt intensity according to the 1998 NHC Best Track. The RMW at the time was about 15 nmi. During the 1940s/50s, there was a full weather station on the island, but it was abandoned during the 1980s. If Mitch occurred during the late 1940s/early 50s, it would have been possible that the Category 5 conditions experienced there would have been recorded directly by an anemometer or indirectly by the barometer. During Hurricane Janet of 1955, which passed directly over Swan Island as a Category 5, the anemometer and barometer failed after recording Category 1 conditions a couple hours before the arrival of the center. However, according to the methodology for this study, stations in operation during the 40s/50s that were not in operation from 1992-2007 that experienced the area inside the RMW of a Category 5 from 1992-2007 would be counted as a Category 5, as is the case with Mitch.

Mitch is listed in the NHC Best Track (Guiney and Lawrence 1999) as a Category 5 from October 26 12Z through October 28 00Z. Figure B1 shows the NHC Best Track for Mitch and the best track likely to be obtained using technology available in the late 1940s/early 50s. On October 27 around 00Z, Mitch passed over Swan Island, where a central pressure of about 910 mb could have been recorded. A central pressure of 910 mb equals 147 kt according to the

Brown et al. southern pressure-wind relationship. A 140 kt intensity is chosen because 5 kt is subtracted for a slow speed. Therefore, if Mitch occurred in the late 40s/early 50s, a peak intensity of 140 kt would be listed instead of the 155 kt peak intensity in the NHC Best Track.

2. Hurricane Emily (2005)

Hurricane Emily (2005) is listed in the NHC Best Track (Franklin and Brown 2006) as having only reached Category 5 strength for six hours (at July 17 00Z) when the center was located approximately 85 nmi south of Jamaica. Figure B2 shows the NHC Best Track for Emily and the best track likely to be obtained using technology available in the late 1940s/early 50s. The observations available that would have been used to determine the peak intensity of Emily are as follows: From July 16 at 1328Z (1718Z) until at least July 17 at 1715Z (July 16 2341Z), the central pressure was less than 950 (940) mb and the aircraft would not have been able to penetrate the center during the late 1940s (early 50s). A central pressure of less than 950 (940) mb yields a wind speed of greater than 113 (123) kt from the intensifying subset of the Brown et al. (2006) southern pressure-wind relationship. Several knots are added to the pressure-wind relationship for a small size and a fast speed, and this rounds to greater than 120 (130) kt. A peak intensity of 125 kt would have been chosen from July 16 12Z to July 17 18Z for the late 1940s, and a 135 kt peak intensity would have been chosen from July 16 18Z to July 17 00Z for the early 1950s. Although Emily passed 85 nmi from Jamaica when it was a Category 5, the hurricane force winds only extended 50 nmi from the center in the northeast quadrant and Jamaica only experienced low-end tropical storm force winds. Therefore, Hurricane Emily likely would not have been listed as a Category 5 hurricane if it had occurred during the late 1940s or early 1950s.

3. Hurricane Dean (2007)

Hurricane Dean (2007) is listed as Category 5 in the NHC Best Track (Franklin 2008) on August 18 from 06-12Z and again on August 21 from 00Z to the 0830Z landfall in Mexico. The Best Track comparison graph for Hurricane Dean is shown in Figure B3. On August 17 at 2332Z, aircraft recorded a 946 mb central pressure, and on the 18th at 1323Z, aircraft would not have been able to penetrate the center in the early 1950s because the pressure was less than 940 mb. A pressure of less than 940 mb yields greater than 123 kt according to the intensifying subset of the southern pressure-wind relationship. After adding 5 kt for a fast speed/small size, a wind speed of greater than 128 kt is obtained. A 135 kt intensity is chosen for the peak early 1950s intensity from August 18 at 06Z through August 19 at 00Z. A peak late 1940s intensity of 130 kt would have been chosen on August 18 from 00-18Z. The central pressure of Dean stayed below 940 mb through the Category 5 landfall, which occurred at 0830Z on the 21st.

Dean made landfall as a 150 kt Category 5 hurricane along the sparsely populated coastline of Costa Maya, Mexico, which had very few people and no observation stations. No surface observations near Category 5 intensity were recorded in 2007 during this landfall. Dean's landfall occurred ~25 nmi ENE of the station at Chetumal, Mexico, which operated during the 40s/50s. The RMW of Dean at landfall was approximately 10-15 nmi. By the time Dean made its closest approach to Chetumal (~20 nmi) about two hours later, the intensity likely had already decreased to Category 4 strength. A 125 (130) kt landfall intensity is chosen for the late 1940s (early 50s) periods as the aircraft would have been unable to penetrate the center. The distance from Chetumal was taken into account, and conditions experienced there likely were not in excess of Category 3 conditions. Since there would have been no surface observations of

Category 5 conditions, Dean would have likely been listed with a peak intensity of Category 4 strength for both the late 1940s and early 1950s. The ACE of Dean would have been slightly higher than in the NHC Best Track utilizing the technology of the early 1950s. This is mainly due to intensity analyses during the first few days of Dean's life. Also contributing to the higher early 1950s ACE is the methodology to decrease the intensity by 25 kt per day backwards from August 16 at 18Z, when a 90 kt intensity was assigned based on a 974 mb aircraft central pressure (recall this methodology was also used in Isabel).

4. Hurricane Felix (2007)

Figure B4 shows that Hurricane Felix (2007) is listed as Category 5 in the NHC Best Track (Beven 2008) from September 3 00Z-12Z and again on September 4 at 12Z (the point right at landfall). As mentioned in Section 2, there were no reconnaissance flights south of 15N between 70W and the coast of Central America. For the entire time Felix was a Category 5, it was located south of 15N as it traveled through the Caribbean. However, during 1944-53, there were not many TCs in that region, and there were reconnaissance flights that occurred there in 1954-1955, so it is believed that if there was a TC there from 1944-53, reconnaissance flights would have been performed. On September 2 at 2307Z, the aircraft in the late 1940s (early 50s) likely would have been unable to penetrate the center since the central pressure was below 950 (940) mb, and this continued through at least September 3 at 1227Z (in the early 1950s, a 942 mb central pressure would have been measured at 1227Z). For the intensity on September 3 at 00Z, a central pressure of less than 950 (940) mb yields a wind speed of greater than 113 (123) kt according to the intensifying subset of the Brown et al. southern pressure-wind relationship. At that time, the cyclone's forward motion was a fast 17 kt and its radius of outer closed isobar

(ROCI) was a small 125 nmi so 10 kt is added to the pressure-wind relationship. This yields an intensity of greater than 125 (135) kt after rounding to the nearest 5 kt value. Therefore, 130 kt is chosen for the late 1940s and 140 kt is chosen for the early 1950s on September 3 from 00-06Z. Felix therefore likely would have been listed as a Category 5 hurricane if it had occurred during the early 1950s period, but likely not during the late 1940s period.

Felix made landfall in Nicaragua as a Category 5 on September 4 at 12Z. The coastal station of Puerto Cabezas, Nicaragua was located about 20 nmi from the center at the time of the 140 kt landfall. This station was in operation during the 1940s/50s as well as in 2007. During Felix, the station's barometer and anemometer stopped working before the peak of the storm. According to the methodology, if the station was located at or inside the RMW during the passage as a Category 5, it would be counted as a Category 5 landfall. The RMW of Felix was about 10 nmi when the center passed ~20 nmi north of the station. Since the station was located approximately 10 nmi outside the RMW of the typically weaker (left) side of the cyclone, it is analyzed that Category 5 conditions would not have been experienced there, especially since the peak intensity of the cyclone was only 140 kt at the time (according to the NHC Best Track). The area along the coast north of that is very sparsely populated until Cape Gracias, which was ~40 nmi north of the landfall point. A late 1940s/early 50s intensity of 120 kt is chosen for the landfall based on the last aircraft fix, which measured a 953 mb central pressure 16 hours before landfall, and taking into account how close Felix passed to Puerto Cabezas.

REFERENCES

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Franklin, J. L., and D. P. Brown, 2006: Hurricane Emily, 11–21 July 2005. National Hurricane Center Tropical Cyclone Rep., 18 pp. [Available online at http://www.nhc.noaa.gov/pdf/TCR-AL052005_Emily.pdf.]

Guiney, J. L., and M. B. Lawrence, 1999: Hurricane Mitch, 22 October–05 November 1998. National Hurricane Center Tropical Cyclone Rep. [Available online at http://www.nhc.noaa.gov/1998mitch.html.]

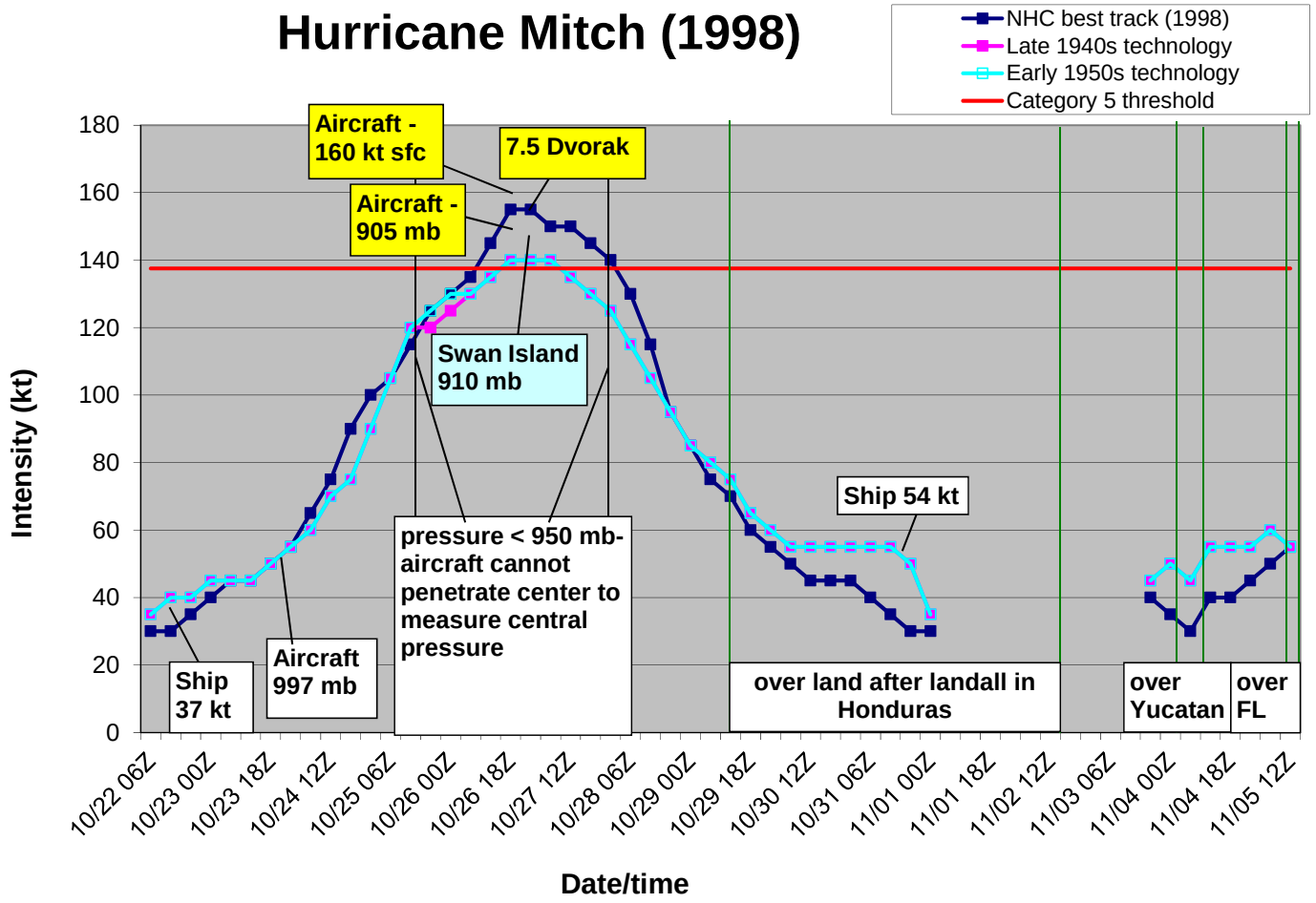

Fig. B1. Best Track comparison graph for Hurricane Mitch (1998). Dark blue line is the NHC Best Track intensity and light blue line is what the intensity would have likely been with observations available during the early 1950s. The intensity derived from late 1940s technology is shown in pink if it differs from the early 1950s values. Yellow boxes indicate observations that would only be available with recent technology and white boxes indicate observations that were available during both the late 1940s/early 50s and today. Light blue boxes indicate observation sites that operated in 1944-53 but not in 1992-2007. Vertical green lines indicate landfall/oceanfall times.

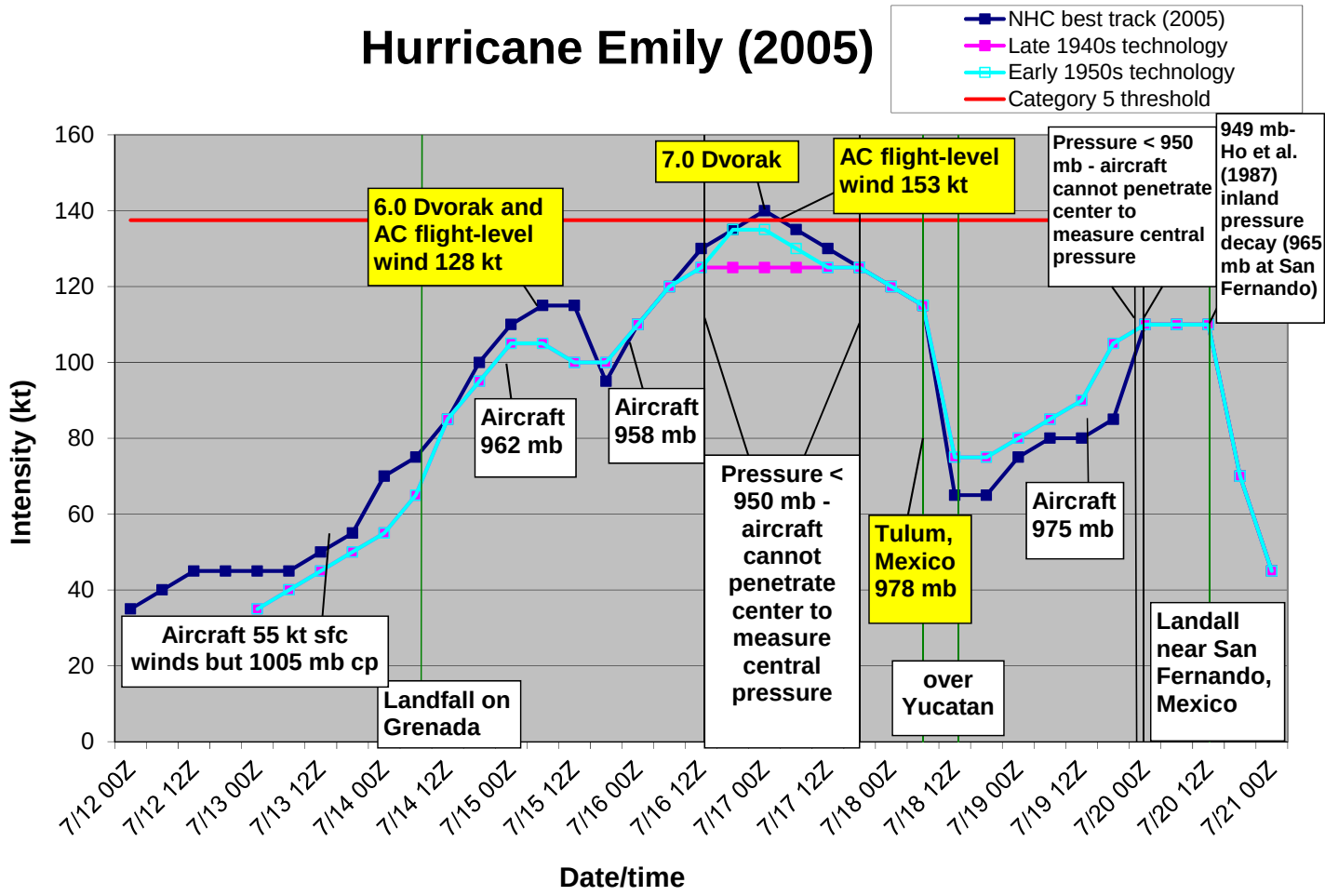

Fig. B2. As in Fig. B1, but for Hurricane Emily (2005).

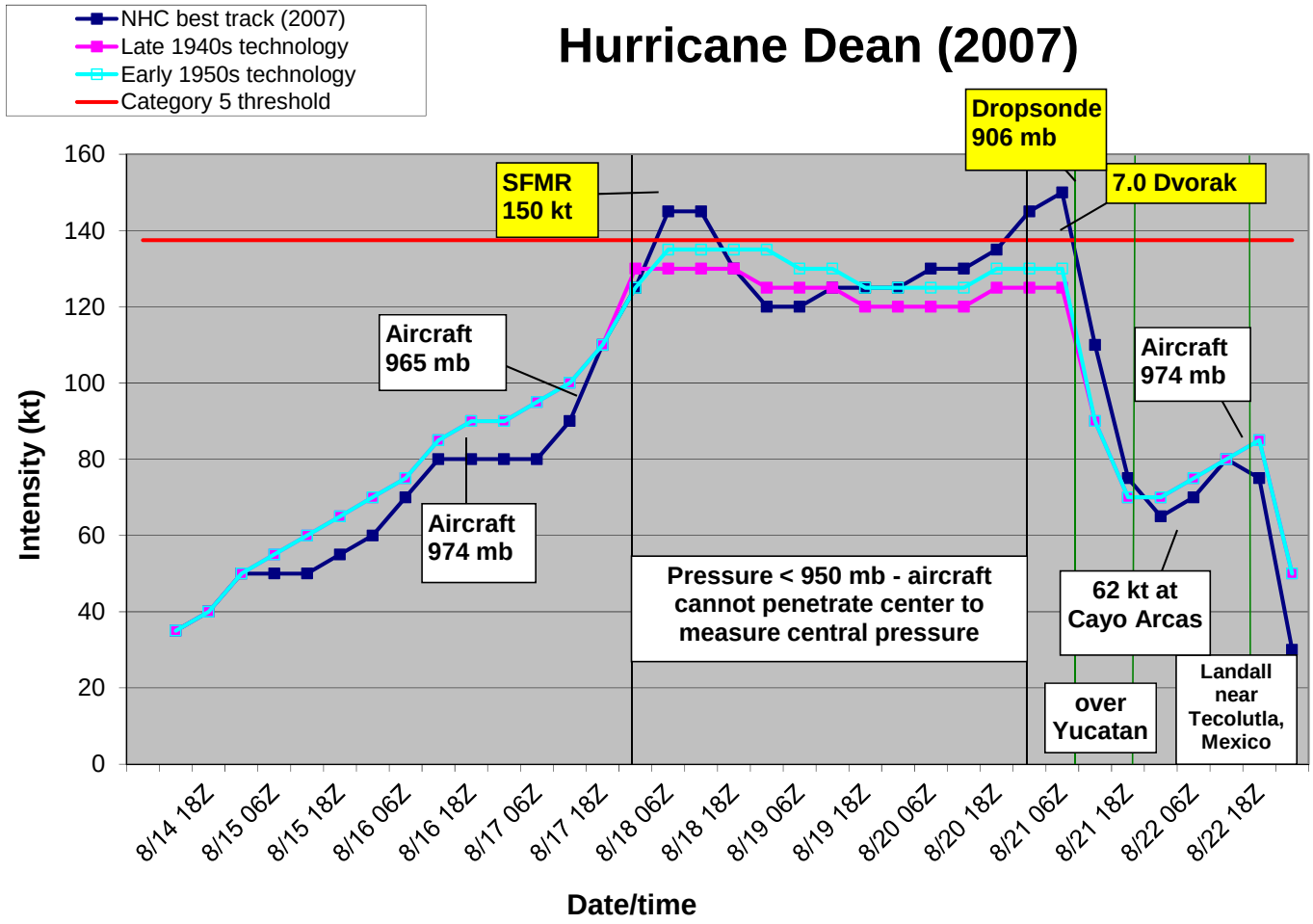

Fig. B3. As in Fig. B1, but for Hurricane Dean (2007).

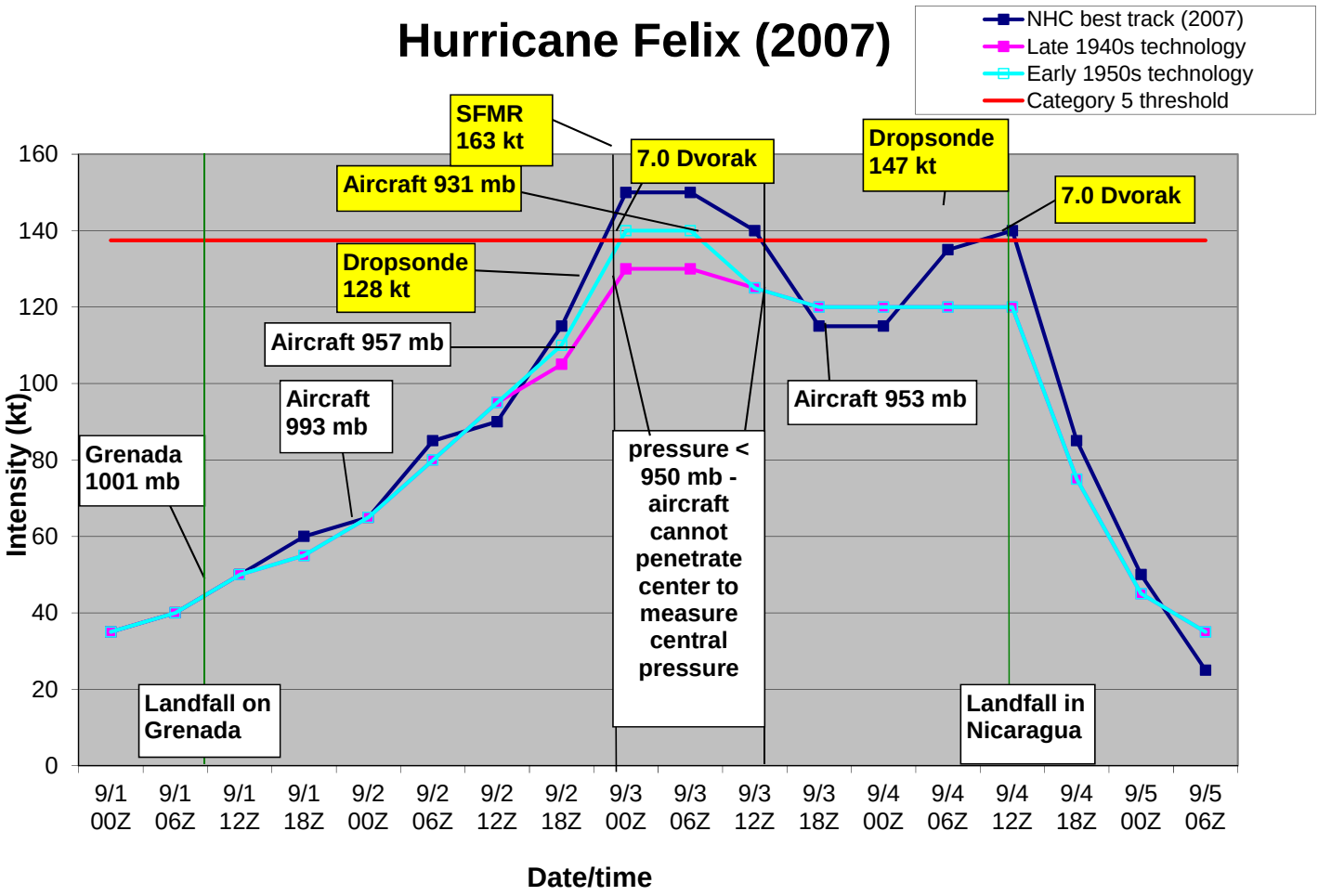

Fig. B4. As in Fig. B1, but for Hurricane Felix (2007).