iCyclone Chase Report

storm	**Hurricane DORIAN**		
location	Marsh Harbour, Great Abaco Island, Bahamas		
date	01 September 2019		
chasers	Josh Morgerman	**author**	Josh Morgerman

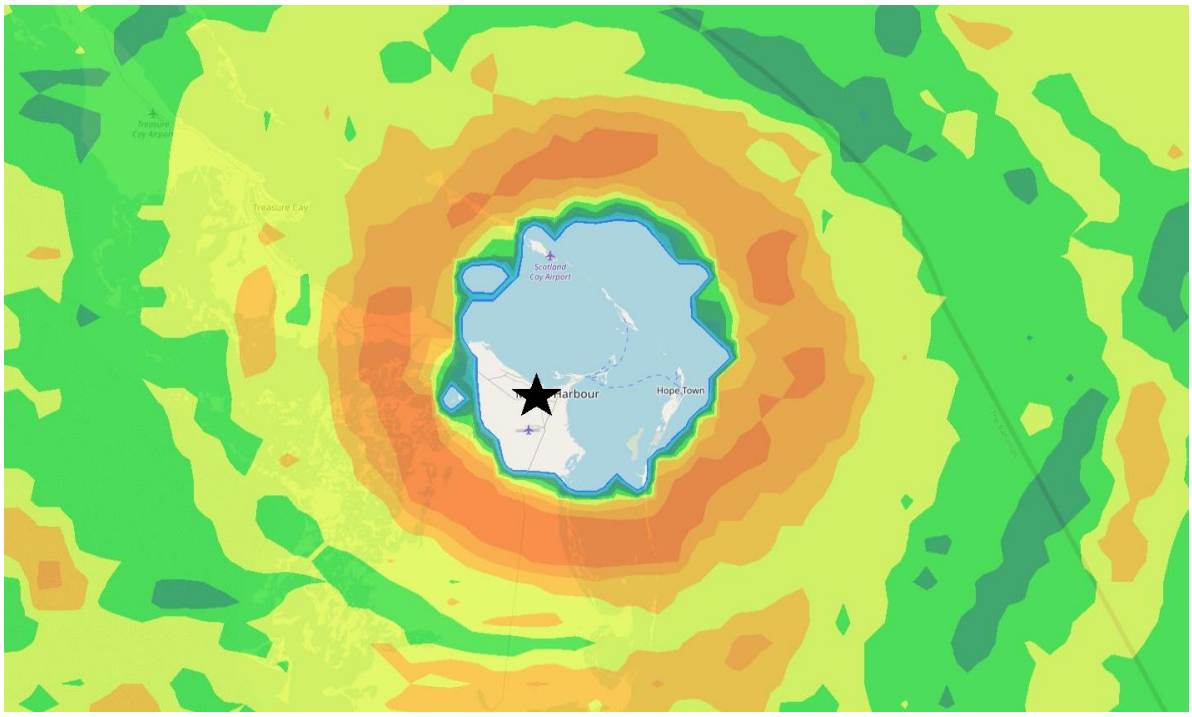
Overview

Hurricane DORIAN was an extremely intense, Category-5 hurricane that made a direct hit on Great Abaco Island in the Bahamas on 01 September 2019.

The author was in the town of **Marsh Harbour on Great Abaco Island** (26.5392N 77.0803W) to document this event—near the landfall point, in the path of the eye.

Key observations:

- **Duration.** The hurricane's core—accompanied by violent and destructive winds—lasted ~4.5 hours: from ~11:25 am to around 4 pm EDT.
- **Eye passage.** The eye brought a lull lasting almost 1.5 hours—from ~1:05 pm to ~2:30 pm.
- **Minimum Pressure.** The lowest pressure was 913.4 mb at 1:50 pm EDT, during the eye.
- **Extreme pressure gradients in inner core.** There were tremendous air-pressure changes over short time periods as the eye neared the author's location. Assuming the cyclone's forward speed was 6 kt, these changes suggest incredible gradients—up to **12.4 mb/n mi.**
- **Inner-eyewall pressure fluctuations.** In the outer portion of the eyewall, pressure fell steadily. In the inner portion of the eyewall—where conditions were more turbulent and violent—pressure fluctuated erratically, hinting at mesovortices. These fluctuations continued in the eye.
- **Subjective Intensity.** Conditions in the inner eyewall were the most extreme this author has witnessed in 48 hurricane cores, including four other Category 5s: DEAN 2007, HAIYAN 2013, MANGKHUT 2018, and MICHAEL 2018.
- **Impact.** Wind and storm-surge damage across Marsh Harbour was **catastrophic.**



Location

The author observed the passage of **Hurricane DORIAN** in **Marsh Harbour, on Great Abaco Island,** at **26.5392N 77.0803W (Location A).**

This location is the Great Abaco Primary School on Central Pines Drive—in a ground-floor, solid-concrete classroom at the W end of the front-W wing of the building. This was very close to the cyclone's landfall point, only **~2.3 n mi N of the hurricane's center** (at its point of closest approach) and only ~**2.6 n mi NE of the 2 pm EDT advisory position.** The author set up at this location more than 8 hours before the cyclone's core reached Marsh Harbour, remaining there until the calm eye arrived. ***This was the author's main location during the storm, and where all data were collected.***

Heavy wind damage to the school necessitated relocating (during the calm eye) to the Bahamas Government Complex—a larger, sturdier building ~0.63 n mi to the ESE, at 26.5365N 77.0688W **(Location B).**

- **Fig 1: Chase Map** shows **the author's main observation point** (**Location A—black star**) in relation to **DORIAN's center** (**colored points**), as per NHC advisory positions.
- **Fig 2: Chase Map (DETAILED)** is a closer view.
- **Fig 3: Chase Map (DETAILED 2)** is an even closer view, showing both the author's main observation point (**Location A—black star**) and **where he relocated to** during the eye (**Location B—blue star**).

Figure 1: Chase Map

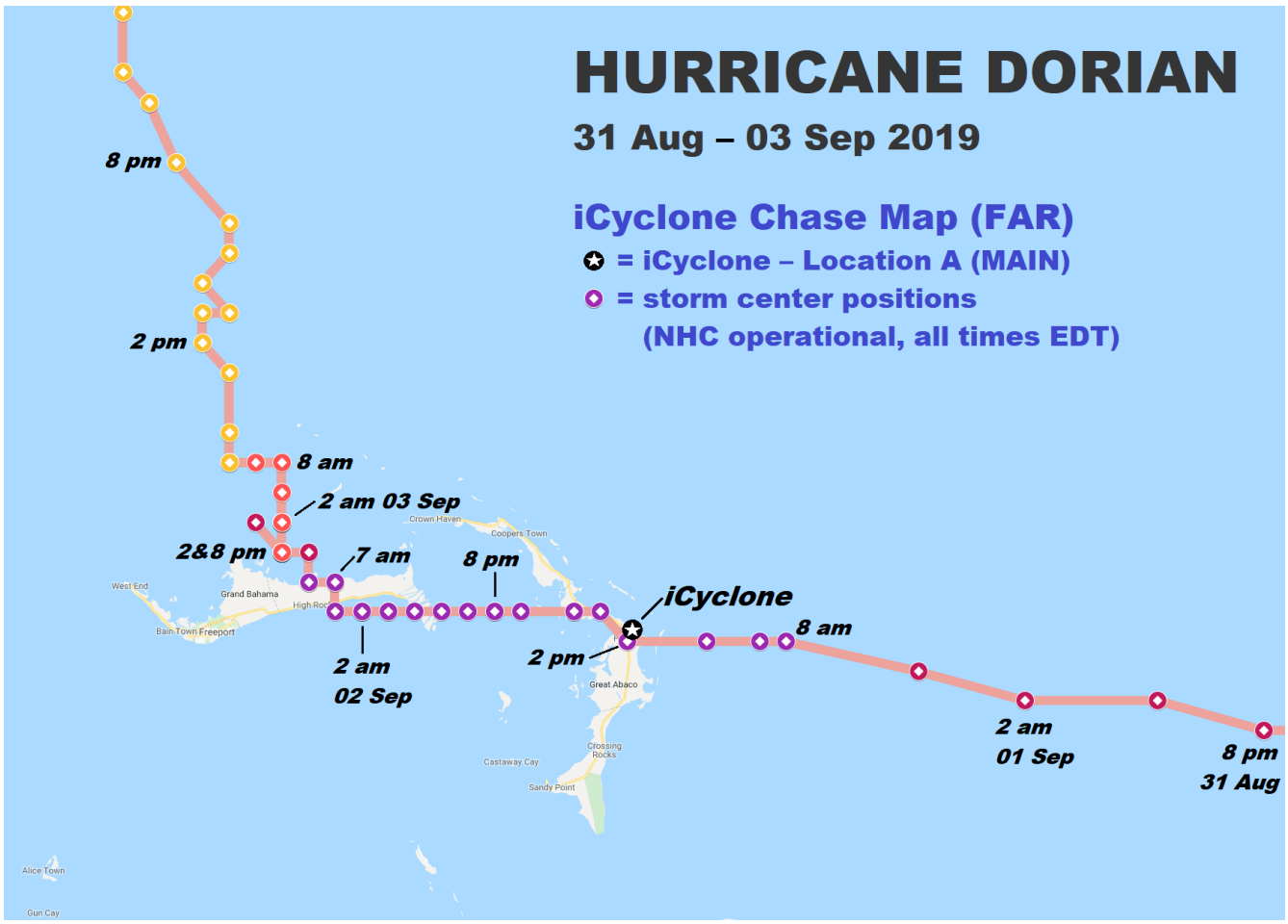


Figure 2: Chase Map (DETAILED)

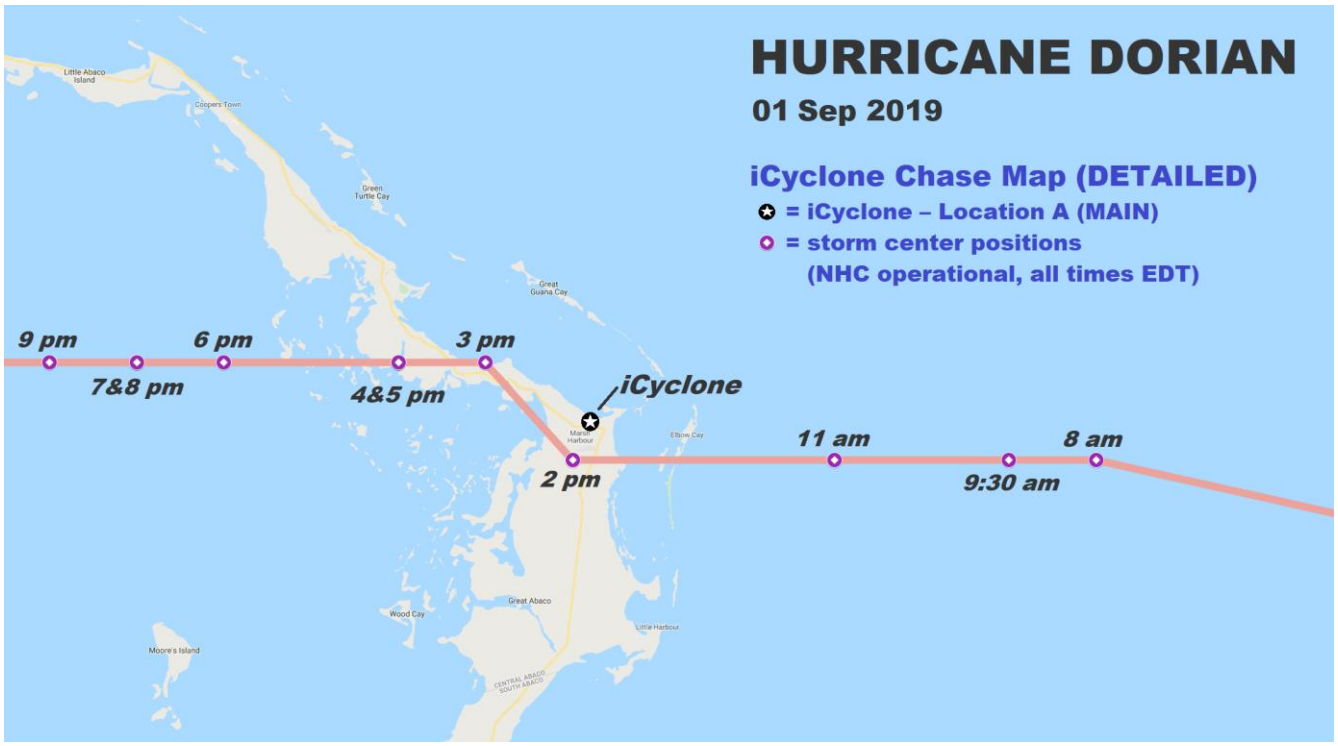
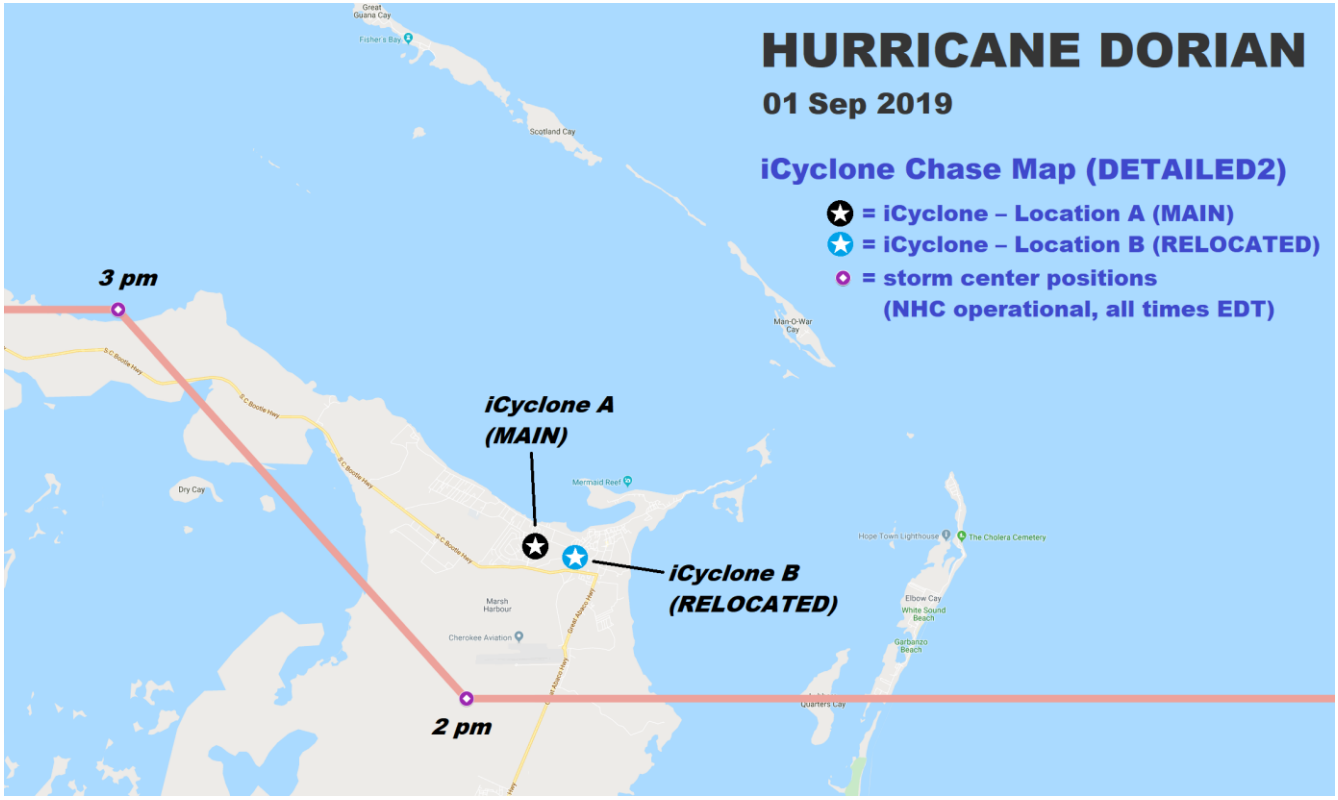
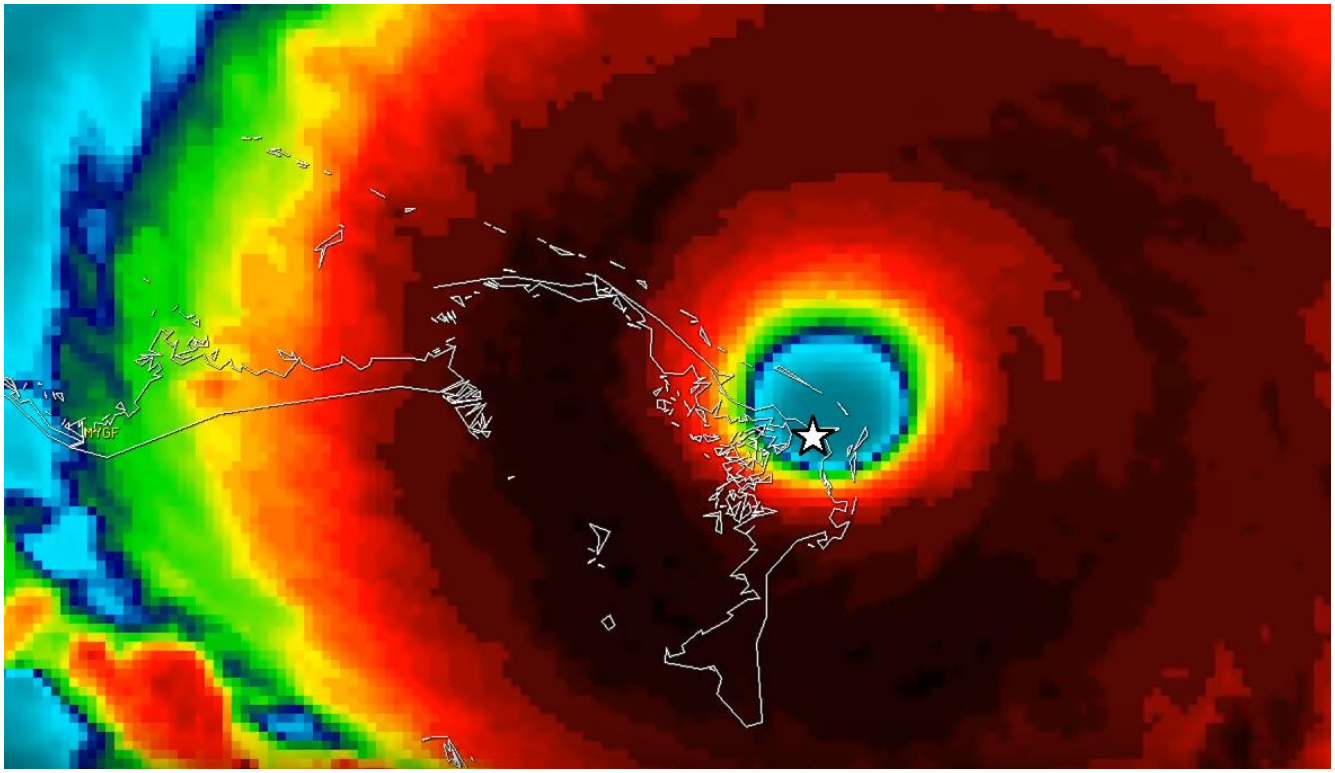


Figure 3: Chase Map (DETAILED 2)



Chronology

DORIAN made landfall on Great Abaco Island, very near Marsh Harbour. The slow-moving hurricane's eye passed directly over the town, bringing a prolonged lull.



Following is a detailed chronology of data and observed conditions at **Location A** (Great Abaco Primary School) in Marsh Harbour during the hurricane's passage—reconstructed from the author's **time-stamped video footage, social-media postings (Tweets) made in real time,** and **air-pressure data.** In most cases, conditions are derived from video footage and rounded to the nearest 5-minute increments.

The hurricane was challenging to observe because of its extreme intensity. The author rode out the brunt of the storm in a small, solid-concrete classroom with 10 other people, observing outside conditions through openings in the shutters on a window on the downwind side of the room.

Color key:

- **Pink = outer portion of eyewall.**
- **Red = inner portion of eyewall (& peak winds).**
- **Blue = relative calm of eye.**
- **Yellow highlight = minimum air pressure.**

Please note that the start and end times of these phases were subjectively determined (without wind data) and should be considered **approximate.** Also note that some air-pressure values indicated in video or real-time Tweets have since been corrected to match data recorded by the device that stayed in a controlled environment during the storm.

All times are **local (EDT):**

iCyclone Chase Report

TIME (EDT)	MB	CONDITIONS
4:00 am	--	Breezy.
6:10 am	1004.0	Rainband sweeping in; gusty winds & moderate rain.
6:45 am	1003.1	Windy; heavy rain.
8:15 am	1000.0	Windy, with occasional strong gusts; moderate rain.
9:30 am	995.9	Strong gusts becoming more common; some roof shingles coming off; light rain.
10:30 am	988.8	Strong & gusty winds; trees bending; moderate rain.
11:00 am	983.0	Windy; moderate rain.
11:20 am	977.4	Wind increasing; trees swaying vigorously; whistling sound; moderate rain.
11:25 am	975.4	Intense, howling winds; heavy rain.
11:40 am	969.8	Intense winds; trees swaying wildly; boards prying off windows; heavy rain.
11:50 am	964.2	Intense, howling winds; nearby tree split in half; rain getting heavier; visibility reducing.
11:55 am	961.5	Roaring winds hammering building; big gusts; nearby tree knocked down; flying debris; heavy rain. People in shelter becoming alarmed.
12:00 pm	958.1	Roaring winds; big gusts; high-velocity flying debris, including large wooden plank; heavy rain.
12:10 pm	953.8	Peak gusts getting stronger; whistling sound; cars in parking lot bouncing; car bumper torn off; flying debris; rain getting heavier.
12:15 pm	949.6	Violent conditions: huge, roaring gusts driving extremely heavy rain; visibility near zero.
12:20 pm	945.5	Violent conditions: tremendous gusts; visibility near zero. Multiple people in shelter experiencing ear pain.
12:25 pm	941.0	Violent conditions: tremendous gusts; moments of whiteout.
12:30 pm	939.8	Violent conditions: roaring winds; 100% whiteout.
12:40 pm	930.5	Violent conditions: roaring winds; 100% whiteout. Boards have torn off windows.
12:55 pm	925.5	Violent conditions: roaring winds. But sky seems to be brightening: light is gleaming through cracks in shutters as we hold furniture against them.
1:05 pm	919.2	Still windy, but much calmer; light rain; visibility dramatically improved.
1:10 pm	920.7	Windy; light rain. Blue sky & stadium eyewall momentarily visible.
1:15 pm	920.0	Windy; light rain. Cars in parking lot thrown around & mutilated; serious damage to building; trees completely stripped as far as eye can see.
1:30 pm	913.8	Breezy; overcast. People in shelter frightened, excitable.
1:50 pm	913.4	Relatively calm; overcast.

The author's shelter was badly damaged, requiring him to relocate during the calm eye to **Location B** (Bahamas Government Complex), ~0.63 n mi ESE of **Location A.** Because the devices needed to be moved, ***all data collection (and detailed observations) unfortunately ended at 1:57 pm EDT, before relocation.***

For the sake of a complete record, following is a partial reconstruction of events at **Location B,** with **approximate** times:

TIME (EDT)	MB	CONDITIONS
2:10 pm	**--**	**Breezy; grey & overcast.**
2:30 pm	**--**	**Wind & heavy rain returning. (Backside of eyewall arriving.)**
2:40 pm	**--**	**Full-on hurricane again. Winds howling & whistling.**
2:50 pm	**--**	**Extreme winds; intense whistling sound; very heavy rain; moments of whiteout.**
4:00 pm	**--**	***(This is the author's best estimate of when the hurricane's core cleared Marsh Harbour.)***
5:15 pm	**--**	**Much calmer but still very windy; light rain.**
5:45 pm	**--**	**Squall: strong winds, heavy rain.**

Key Observations

- The **destructive core** of the cyclone (including the eye) took **~4.5 hours to pass.**
- The **inner portion of the eyewall was more violent and turbulent** than the outer portion, bringing a complete whiteout. The most spectacular damage—include cars being thrown—seemed to happen behind this "cloak of whiteness."
- Marsh Harbour was in the **eye** for approximately **1 hour 25 minutes**—with the lull lasting from ~1:05 pm to ~2:30 pm EDT.
- The **lowest air pressure, 913.4 mb,** occurred at **1:50 pm EDT**, inside the eye.

A fleeting glimpse of the stadium eyewall structure—caught by author's camera at 1:12 pm EDT.

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Air Pressure Data

The author collected quality-controlled air-pressure data with two Kestrel 4500s.

Both devices were deployed at **Location A,** a ground-floor, solid-concrete classroom at the Great Abaco Primary School (coordinates: 26.5392N 77.0803W).

- **Device A**
  - **Placement:** In a desk drawer, a few feet above the floor.
  - **Deployment time:** 7:38 am – 1:57 pm EDT.
  - **Sampling rate:** 1 reading per 30 seconds (**2/min**).

- **Device B**
  - **Placement:**
    - Initially placed on the ground near the entrance to the school.
    - Then moved to the floor of a classroom (**Location A**), very near—and at the same elevation as—the initial location, well before the arrival of the hurricane's eyewall.
    - Then moved to the same desk drawer as **Device A** at the height of the storm (because the room began to flood).
  - **Deployment time:** 5:16 am – 1:56 pm EDT.
  - **Sampling rate:** 1 reading per minute (**1/min**).

Device A recorded for a shorter time—however, this device's data are preferred because 1) it remained essentially undisturbed the entire time and 2) it sampled twice as frequently as **Device B**, yielding a more detailed data profile.

Although **Device B** was moved twice, these moves were insignificant in terms of location and elevation, and the data are considered valid.

The pressure traces for **Devices A and B** are below: **Fig 4: Barogram—DEVICE A** and **Fig 5: Barogram—DEVICE B**.

Calibration

Location A (where all data were collected) is on a hill, well above sea level. To estimate the elevation, the author used a Kestrel 4500 as a pressure altimeter (from a starting point at the beach, approx. ~700 meters away, at sea level). This yielded an elevation of **~36 ft** for the surface of the parking lot in front of the school.

Considering this, to yield **sea-level air pressure** the devices were calibrated as follows:

- **Device A.** A **reference altitude of 40 ft** was used—which is the estimated elevation (36 ft) plus 4 ft to account for the device's height above the surface of the parking lot. (It was in a desk drawer in a ground-floor classroom.)

- **Device B.** A **reference altitude of 38 ft** was used—which is the estimated elevation (36 ft) plus 2 ft to account for the device's height above the surface of the parking lot. (It was on the ground outside, then on the floor of a ground-floor classroom inside, then in a desk drawer in the classroom.)

Later on, geographer James Hyde analyzed NASA SRTM data and estimated the ground elevation at the observation location to be **28-32 ft.** If Hyde's estimate is correct, then the author's estimate was ~5 ft too high. However, for calibration purposes this difference is insignificant, as it would cause the sea-level pressure readings to be **at most** 0.2 mb too high—a negligible discrepancy and well within the accuracy range of the devices.

Minimum Pressure

Devices A and B matched well, showing similar minimum readings almost simultaneously a little before 2 pm, as the cyclone's eye was passing over the observation point:

- **Device A: 913.4 mb at 1:50 pm EDT**
- **Device B: 913.7 mb at 1:53 pm EDT**

As both devices are considered accurate and reliable, iCyclone's official minimum pressure during Hurricane DORIAN is **913.4 mb**.

As mentioned above, the author's shelter was badly damaged in the front side of the hurricane, requiring him to relocate during the calm eye. Because the devices needed to be moved, ***all data collection unfortunately ended at 1:57 pm EDT, before relocation.*** While the data indicate the air pressure had already bottomed out and was starting to recover, there's no way to know for sure if the true minimum had already occurred. ***It's therefore possible these data don't reflect the true minimum pressure at this location.***

The complete data for both devices are graphed in **Figures 4** and **5**, below.

Inner-Core Pressure Fluctuations

When the **outer** edge of the eyewall reached the observation point at ~11:25 am EDT, the air pressure continued to drop **rapidly and steadily,** creating a relatively smooth pressure trace.

Once the **inner** portion of the eyewall arrived, the pressure dropped even more rapidly, **and with volatile fluctuations,** creating a jagged pressure trace. These pressure fluctuations coincided with noticeably more violent conditions, and they suggest embedded eyewall mesovortices. Interestingly, these fluctuations continued well into the eye.

Fig 6: Barogram—DEVICE A (Pressure Fluctuations) is a close view of the data recorded by **Device A** during the passage of the cyclone's intense core, highlighting both the **smooth** pressure drop in the outer portion of the eyewall and the **jagged** drop in the inner portion.

Core Gradient

The data suggest **extremely** steep air-pressure gradients in DORIAN's inner core—great pressure changes over small distances that are by far the highest this author has measured.

Methodology

The cyclone's forward speed was used to calculate how much time it took for each nautical mile of the cyclone to pass the author's fixed location. Gradients were then calculated by noting the change in pressure across these 1-n-mi samples of the cyclone:

1. As per NHC advisories, DORIAN was moving steadily W at **6 kt** during the time it approached and passed over Marsh Harbour.
2. Using this forward speed, it was assumed the author's fixed location sampled **1 n mi** of the cyclone every **10 minutes.**
3. Pressure changes over 10-minute periods were therefore understood to indicate the pressure differences (gradients) across 1-n-mi samples of the cyclone.

Peak Gradients

Applying this methodology, spectacularly steep gradients were noted in the inner portion of the hurricane's eyewall—on both devices:

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Device A

- **10.7 mb/n mi** from **12:14 to 12:24 pm EDT** (derived from a **10.7-mb drop** over 10 minutes).
  - The air pressure also dropped **10.3 mb** from 12:12 to 12:22 pm EDT and **10.0 mb** from 12:16 to 12:26 pm EDT.
  - This fast drop (collectively from 12:12 to 12:26 pm EDT) occurred just as the intense inner portion of the eyewall was reaching the observation point, and it coincided with a noticeable increase in the wind's violence.

- **12.4 mb/n mi** from **12:31 to 12:41 pm EDT** (derived from a **12.4-mb drop** over 10 minutes).
  - This peak gradient was sampled deep in the inner portion of the eyewall.

- **11.2 mb/n mi** from **12:54 to 1:04 pm EDT** (derived from a **11.2-mb drop** over 10 minutes).
  - This drop occurred just moments before the arrival of the calm eye.

Device B

Peak gradients recorded on **Device B** were similar to those recorded on **Device A**, and they coincided with the **Device A** peaks almost to the minute:

- **10.2 mb/n mi** from **12:14 to 12:24 pm EDT** (derived from a **10.2-mb drop** over 10 minutes).

- **10.9 mb/n mi** from **12:31 to 12:41 pm EDT** (derived from a **10.9-mb drop** over 10 minutes).

- **10.3 mb/n mi** from **12:52 to 1:02 pm EDT** (derived from a **10.3-mb drop** over 10 minutes).

Fig 7: Barogram—DEVICE A (Peak Gradients) is a zoomed-in view of the data **Device A** collected in the inner portion of the cyclone's eyewall, with the passage of these peak gradients indicated in **yellow**.

Conclusion

Of course, these calculations are rough, with limitations to their accuracy. They assume the cyclone was moving at a perfectly steady forward speed, in a straight line, directly toward the observation point—which may be unrealistic. Also, it's possible extremely localized eyewall features—or even powerful wind gusts passing over the building—caused pressure spikes and dips that weren't representative of the overall pressure profile of the cyclone's core.

That said, the plentiful examples (on both devices) of pressure drops greater than 10 mb within 10-minute periods lend confidence to the author's belief that the peak gradients in DORIAN's inner core exceeded 10 mb/n mi.

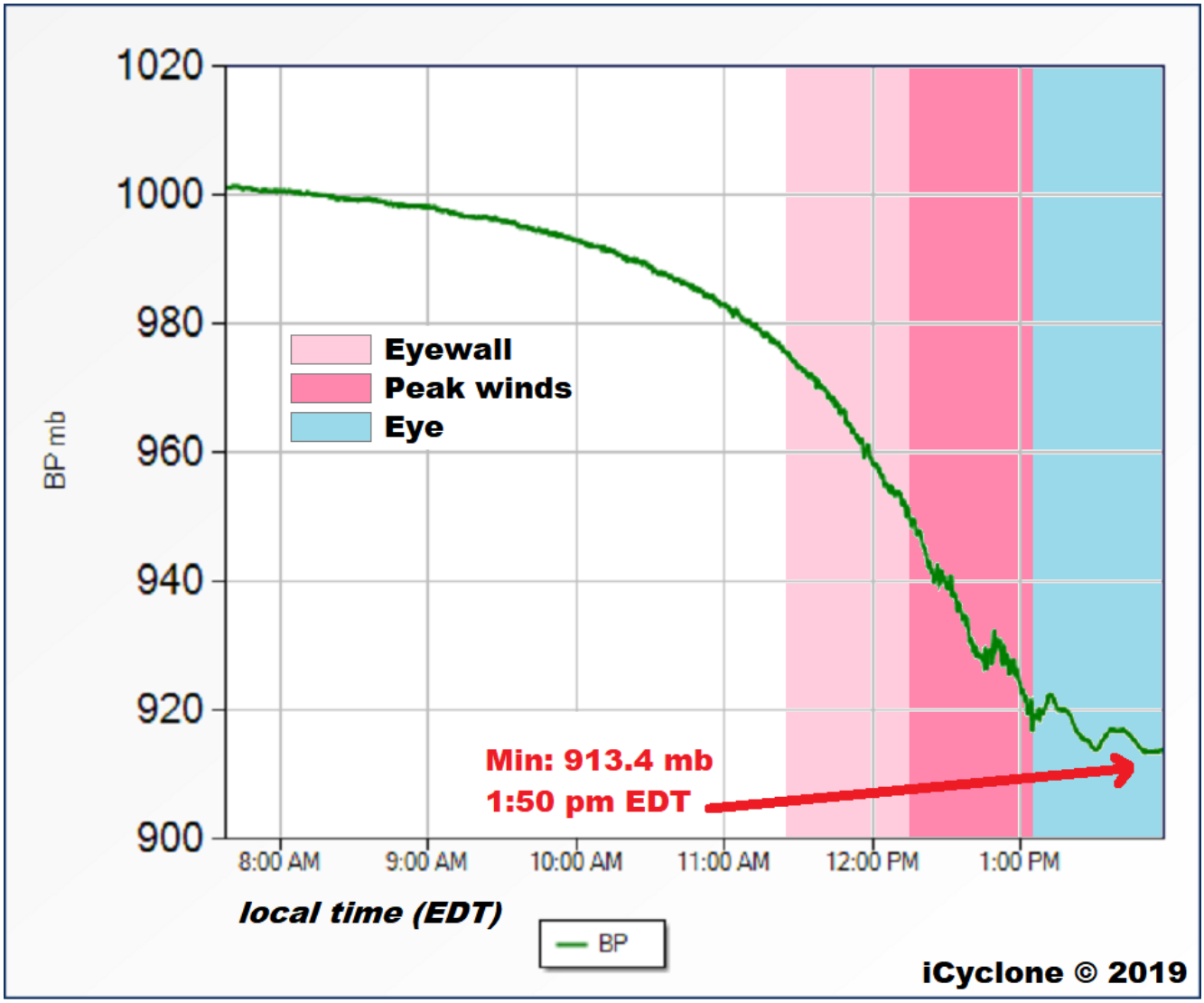
Following is a list of selected intense cyclones in which the author collected core data, **ranked by calculated peak gradient.** DORIAN easily tops the list:

CYCLONE	DATE	LOCATION	WIND	PEAK GRADIENT
DORIAN	01Sep 2019	Marsh Harbour, Bahamas	160 kt	**12.4 mb/n mi**
PATRICIA	23Oct 2015	Emiliano Zapata, JAL, Mexico	130 kt	**10.5 mb/n mi**
MICHAEL	10Oct 2018	Callaway, FL, USA	140 kt	**8.1 mb/n mi**
MARIA	20Sep 2017	Palmas Del Mar, PR, USA	135 kt	**7.1 mb/n mi**
HARVEY	25-26Aug 2017	Rockport, TX, USA	115 kt	**6.3 mb/n mi**
IRMA	10Sep 2017	Naples, FL, USA	100 kt	**5.9 mb/n mi**
ODILE	14-15Sep 2014	Cabo San Lucas, BCS, Mexico	110 kt	**4.6 mb/n mi**

Note: *At the time of this writing, the author has not yet calculated gradients from the data he collected in the inner cores of several other intense cyclones, including Super Typhoon MANGKHUT 2018 (Philippines), Typhoon HAIMA 2016 (Philippines), Typhoon MEGI 2016 (Taiwan), Typhoon NEPARTAK 2016 (Taiwan), Typhoon DUJUAN 2015 (Taiwan), Typhoon GONI 2015 (Japan), Super Typhoon HAIYAN 2013 (Philippines), and Typhoon DANAS 2013 (Japan). It's likely several of these events will place on this list—however, an initial review of the data suggests none will yield peak gradients anywhere near as steep as DORIAN's.*

Figure 4: Barogram—DEVICE A

Air-pressure data reveal the minimum value of 913.4 mb occurred at 1:50 pm EDT, as the cyclone's eye was passing over the observation point. The approximate period of the eyewall is indicated in pink; the period of peak winds in the inner eyewall is emphasized with deep pink; the lull of the eye is indicated in blue.



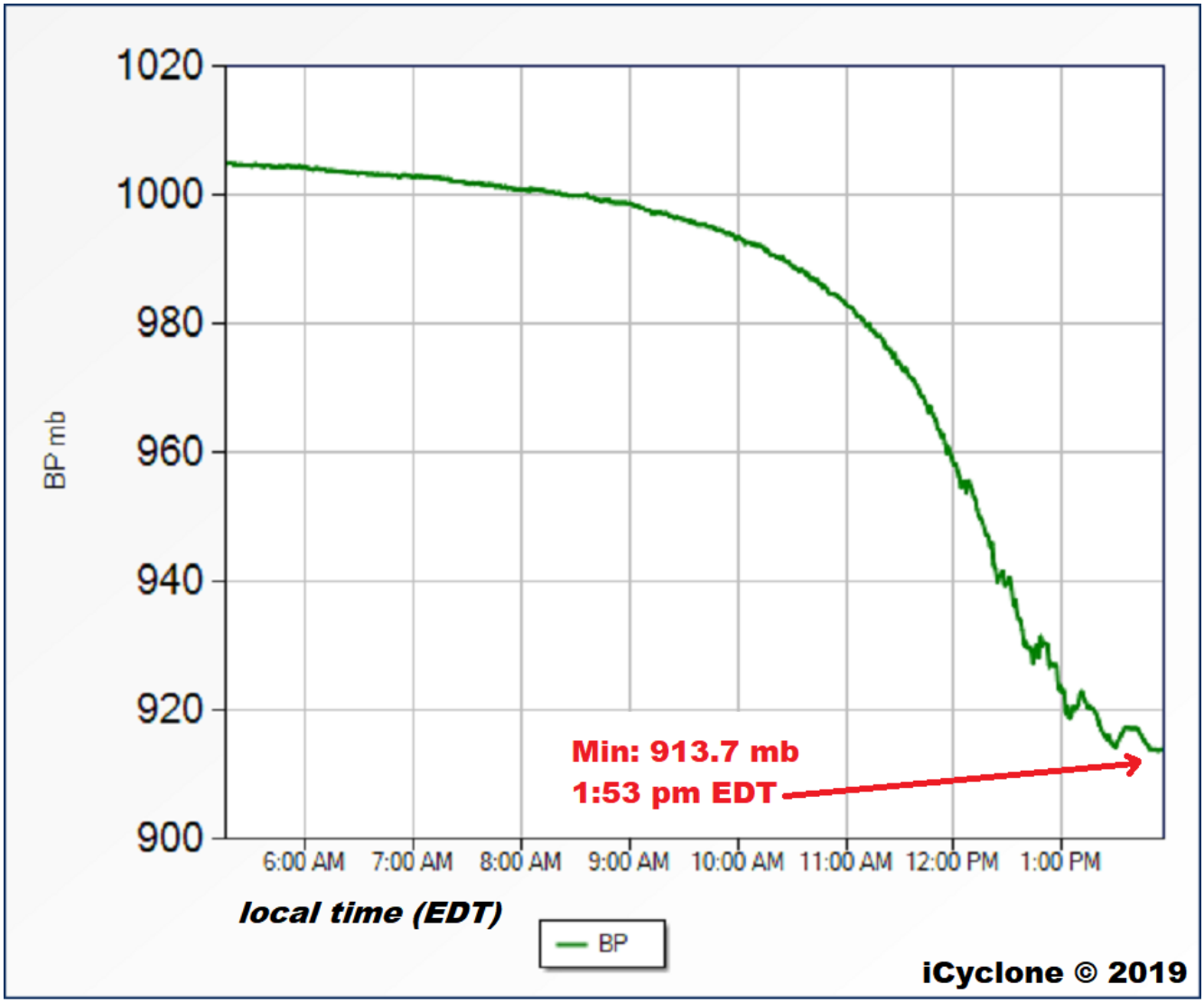
HURRICANE DORIAN: 01 Sep 2019

Marsh Harbour, Great Abaco Island, Bahamas

26.5392N 77.0803W – ref el 36 ft **DEVICE A**

Figure 5: Barogram—DEVICE B

Device B was deployed several hours before Device A, yielding a longer record. The data from Device B firmly corroborate the data from Device A, including not just the depth and timing of the minimum pressure (913.7 mb at 1:53 pm EDT), but also the inner-core fluctuations: the dips and spikes in this trace closely mirror the dips and spikes in the Device A trace.



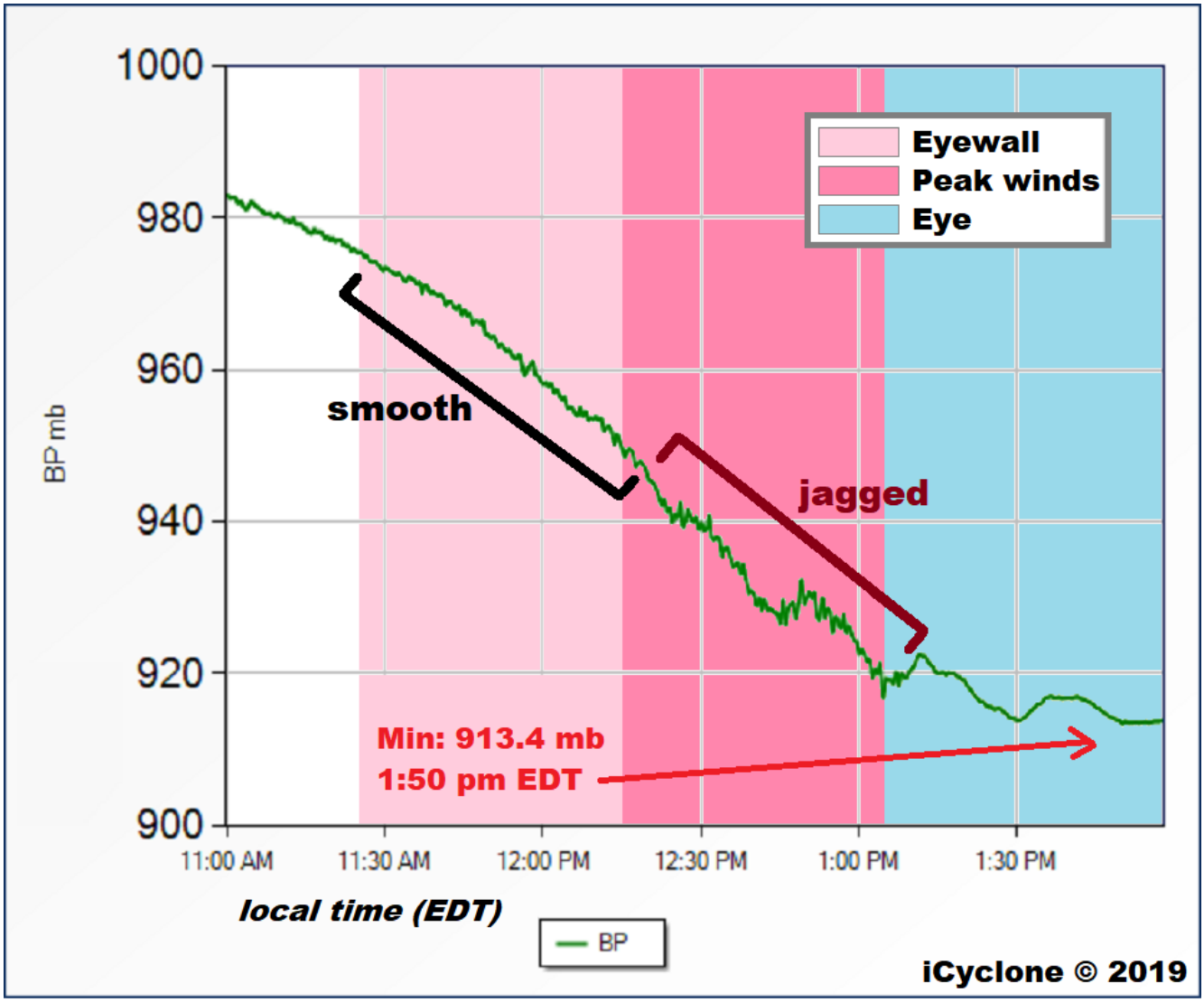
HURRICANE DORIAN: 01 Sep 2019

Marsh Harbour, Great Abaco Island, Bahamas

26.5392N 77.0803W – ref el 36 ft **DEVICE B**

Figure 6: Barogram—DEVICE A (Pressure Fluctuations)

A close view of the hours during which the core of the hurricane passed over Marsh Harbour. Notice the air-pressure fall is relatively steady in the outer portion of the eyewall, then becomes jagged and volatile in the inner portion of the eyewall. These pressure fluctuations suggest embedded eyewall mesovortices. (The time period is just under 3 hours—from 11 am to almost 2 pm EDT.)



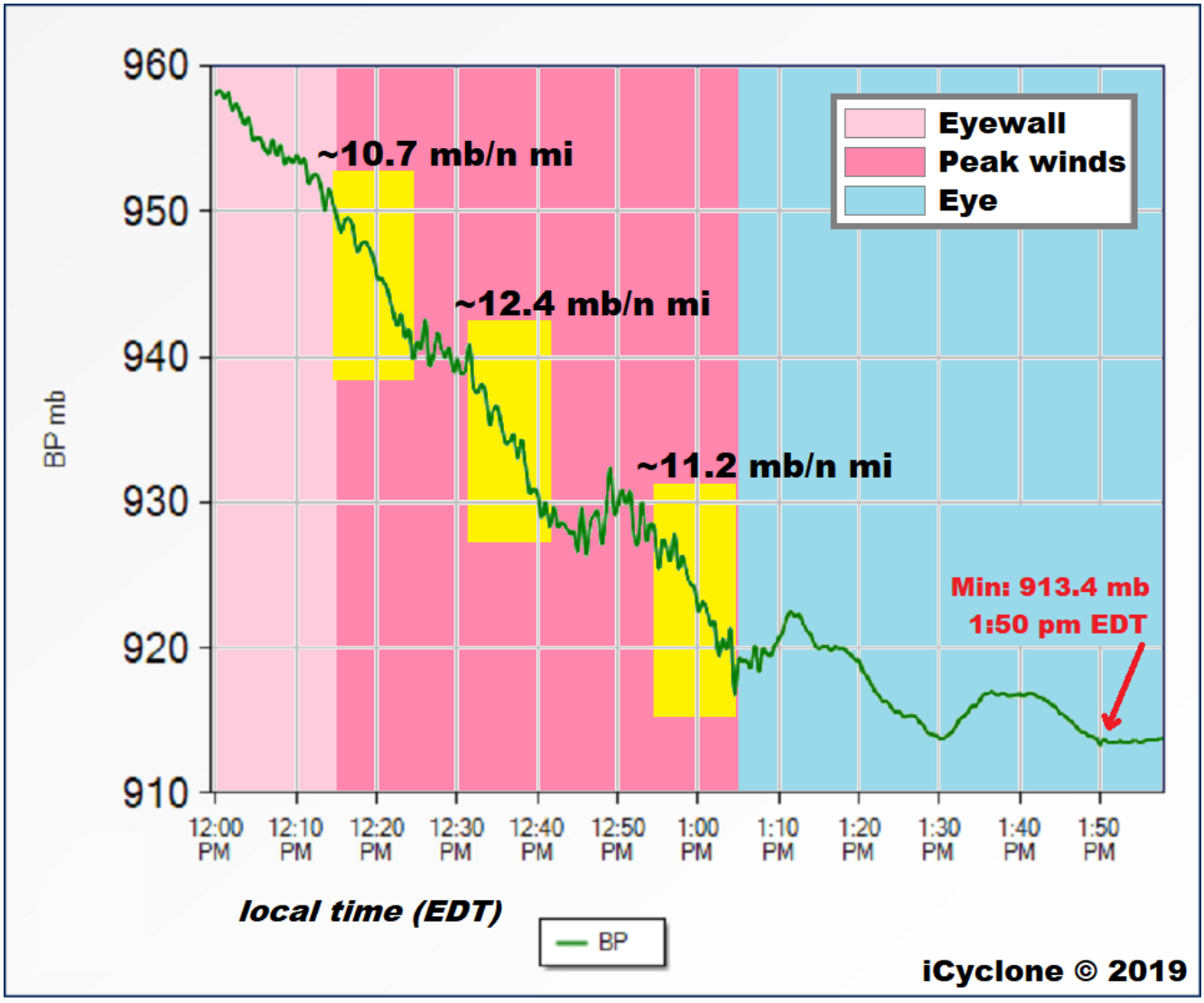
HURRICANE DORIAN: 01 Sep 2019

Marsh Harbour, Great Abaco Island, Bahamas

26.5392N 77.0803W – ref el 36 ft **DEVICE A**

Figure 7: Barogram—DEVICE A (Peak Gradients)

A close view of the final 2 hours of data (from 12 noon to almost 2 pm EDT), during which time the violent inner core of the hurricane passed over the observation point. Notice the peak gradients (yellow) were all measured inside the inner portion of the eyewall (deep pink).

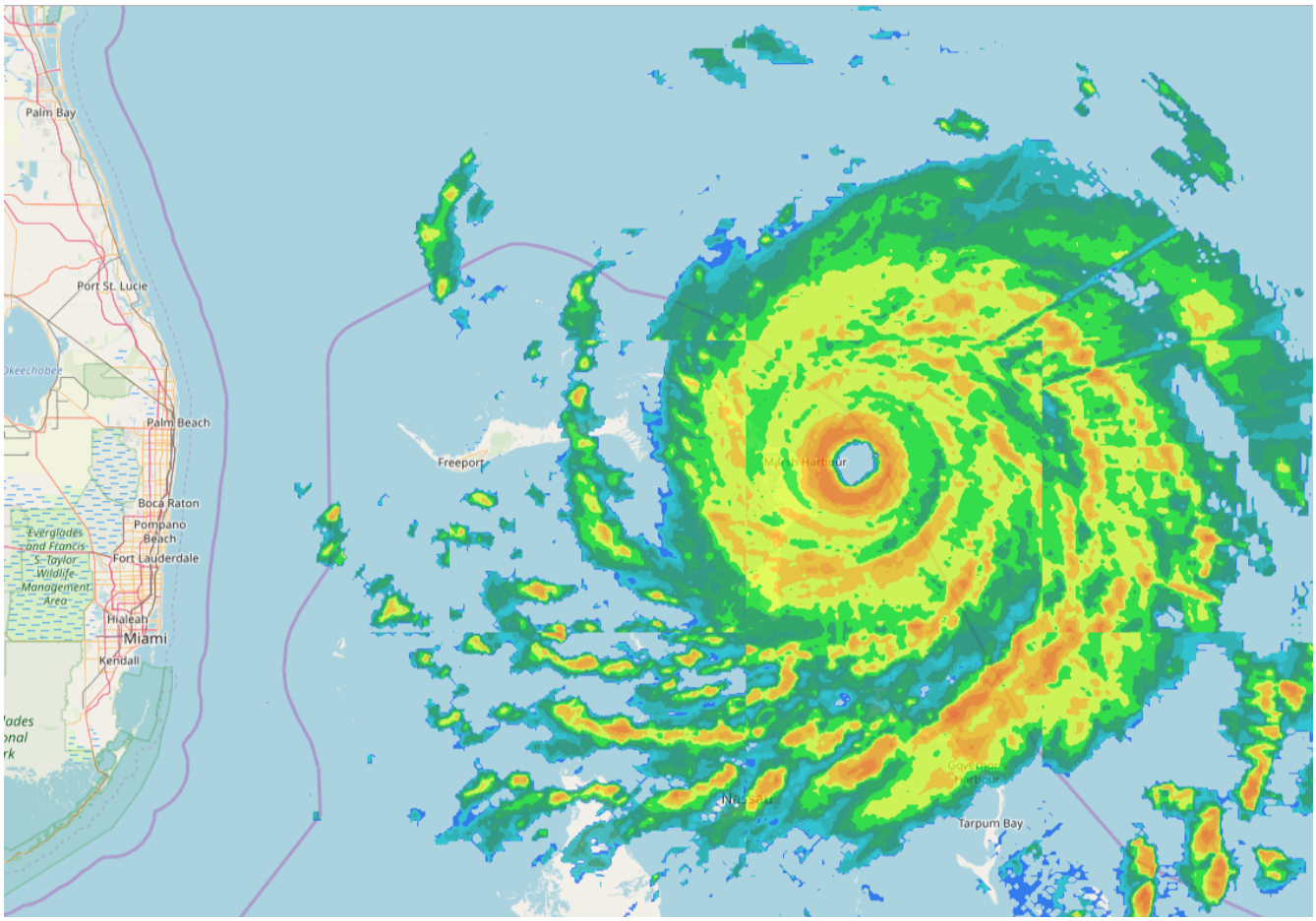


HURRICANE DORIAN: 01 Sep 2019

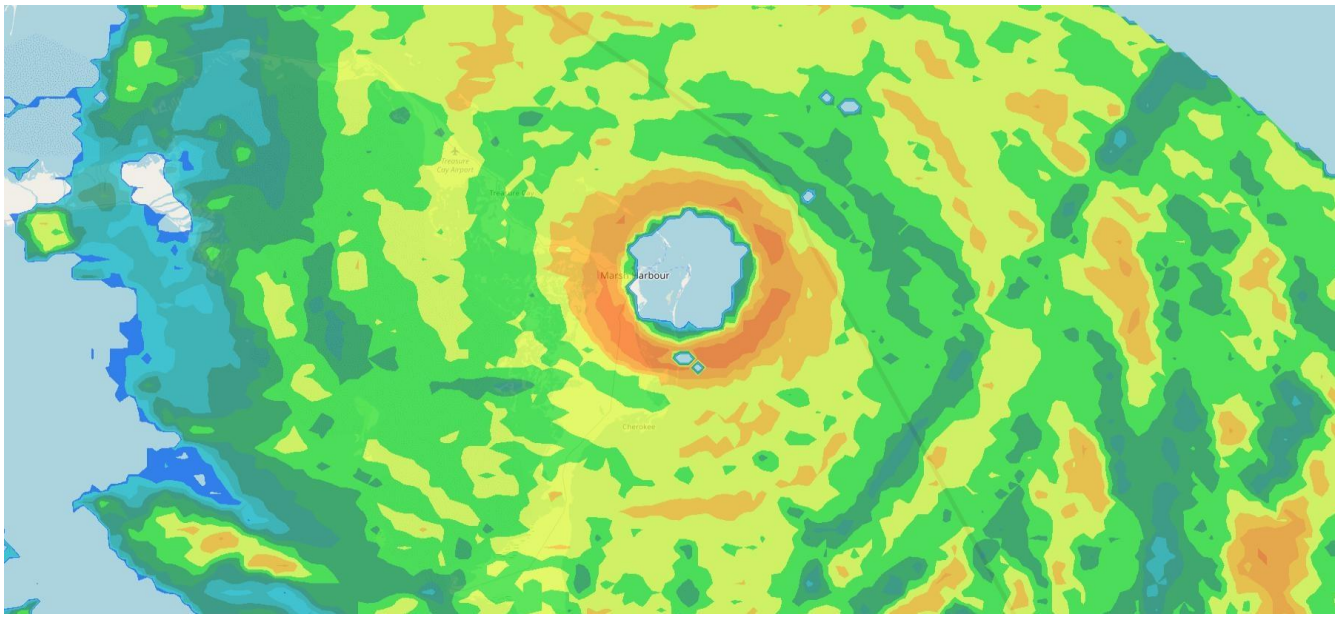
Marsh Harbour, Great Abaco Island, Bahamas

26.5392N 77.0803W – ref el 36 ft **DEVICE A**

Radar Imagery



Hurricane DORIAN bearing down on Great Abaco Island in the Bahamas—perilously close to the densely-populated Gold Coast of Florida.



Hurricane DORIAN's front eyewall pounding Marsh Harbour.

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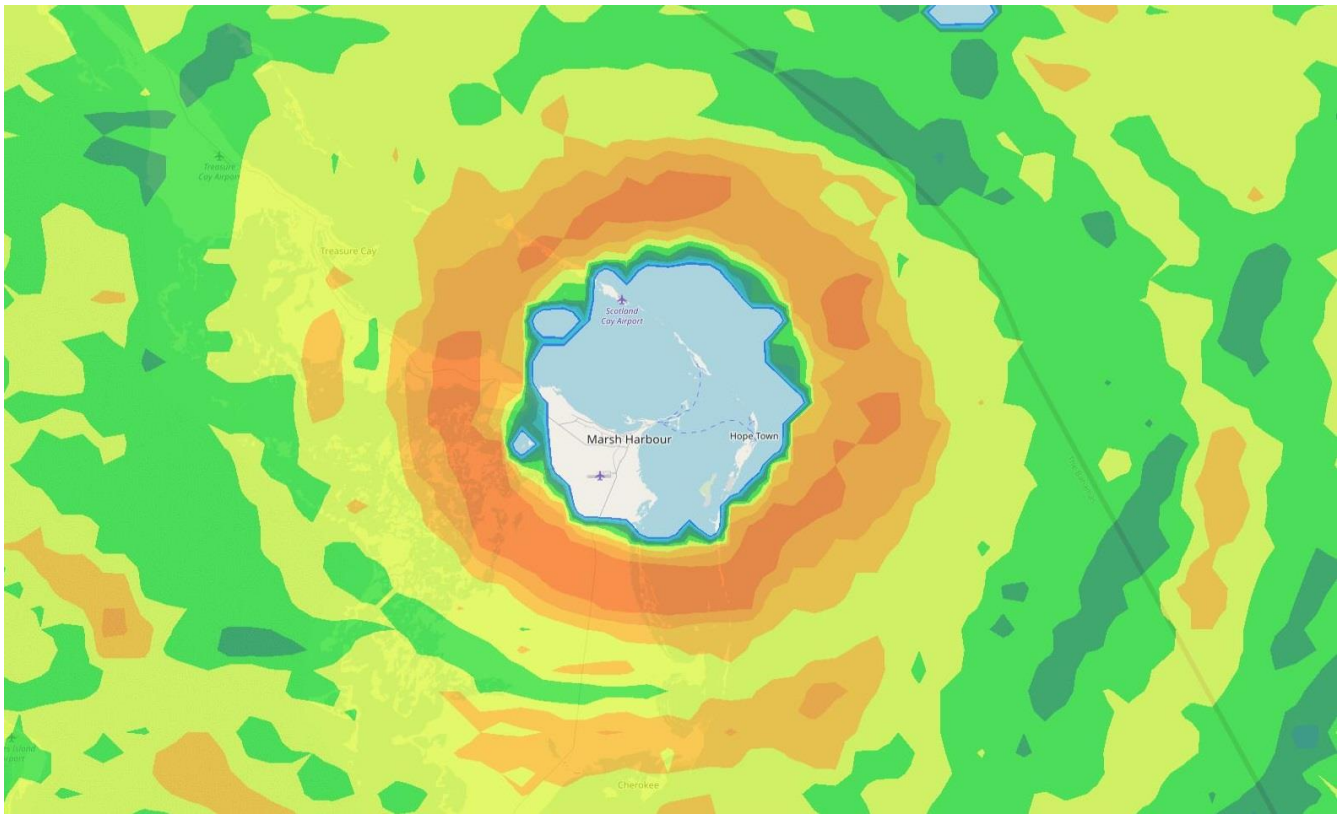

Marsh Harbour squarely inside the calm eye of Category-5 Hurricane DORIAN.

Damage—From on the Ground

Wind and storm-surge damage across Marsh Harbour was catastrophic.

Along the coast, a tremendous storm surge—likely well over 20 ft—swept low-lying areas of the town. The commercial promenade along the waterfront was devastated, with many businesses destroyed. More tragically, the flat, marshy, poorer neighborhoods known as The Mudd and Pigeon Peas were almost completely obliterated, resulting in an unknown number of deaths and injuries. After the hurricane passed and the waters receded, this entire section of Marsh Harbour was simply a vast field of rubble.

Neighborhoods high enough to escape the storm surge—including the author's location at the Great Abaco Primary School and the well-to-do Central Pines subdivision—suffered extreme wind damage. Almost every house and building had heavy structural damage, including smashed walls and roofs torn off. Cars were torn open, mutilated, and thrown like toys. As soon as the whiteout of the inner eyewall cleared away to reveal the calm eye, the author noticed a car sitting on the lawn outside the window that had not been there before the whiteout—and he couldn't ascertain where it came from. In at least one instance—in Central Pines—a car was thrown so far from its original location that the owner thought it had simply disappeared—until she found its mangled shell in a forest on the other side of the street.

The winds so badly damaged the Great Abaco Primary School—a designated shelter, made of concrete, but with wood features—that its frightened occupants needed to relocate to the nearby Bahamas Government Complex during the calm of the eye.

Construction quality mattered. The Government Complex and nearby medical clinic **performed well.** While there was cosmetic damage—including stripped decorative columns and panels torn out of the exterior porticos—the structures withstood the winds: the roofs stayed on, the walls stayed up, and (as far as the author could tell) the impact-glass windows withstood the incredible assault of flying debris.

Following are images of the damage around Marsh Harbour.

A couple embrace as they pick up the pieces after Hurricane DORIAN destroyed their home.

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The author's first sight when he stepped outside into the eye of Hurricane DORIAN: cars jumbled together and smashed concrete littering the ground. Concrete portions of the Great Abaco Primary School mostly withstood Hurricane DORIAN's winds—but not completely.

In the eye Hurricane DORIAN. Cars were mutilated by the violent winds just minutes before.

Much of the Great Abaco Primary School is concrete—but not all of it. Wooden portions of the complex were no match for DORIAN's winds.

The Bahamas Government Complex, days after the hurricane. While there was extensive cosmetic damage, the structure performed well—withstanding the hurricane's tremendous winds and protecting the hundreds who sought shelter inside.

Cars all over Marsh Harbour were thrown around and literally mutilated by the hurricane's powerful winds. Note the Bahamas Government Complex in the background: this apparently well-built structure withstood the storm.

A resident of the Central Pines subdivision salvages belongings from his destroyed home. Well above the storm surge, this neighborhood of Marsh Harbour suffered extreme wind damage.

Hurricane DORIAN's winds tossed cars in the Central Pines neighborhood like toys.

These well-built homes in the Central Pines neighborhood mostly withstood the winds, although they took a beating.

A home completely destroyed by Hurricane DORIAN's winds.

Many houses in Marsh Harbour suffered extreme wind damage in DORIAN. Sights like this were common.

Heavy wind damage to the second floor of a house.

The commercial heart of Marsh Harbour was flattened by storm surge and winds.

Concrete-block buildings in Marsh Harbour's waterfront commercial district were flattened by Hurricane DORIAN's mighty storm surge.

In Marsh Harbour's waterfront commercial district, DORIAN's storm surge acted like a mighty bulldozer, mowing down buildings and leaving heaps of rubble.

The Mudd—a poorer, low-lying neighborhood of Marsh Harbour—was flattened by a tremendous, tsunami-like storm surge. All that was left in its wake was a vast field of rubble.

Another view of the complete destruction in The Mudd neighborhood of Marsh Harbour.

Damage—From Above

Google Maps satellite images of Marsh Harbour from before and after Hurricane DORIAN illustrate the scale of the destruction.

View A: Wide

This wide view includes most of the town center, including the author's two locations during the storm.

Marsh Harbour: BEFORE

Marsh Harbour: AFTER

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View B: Central Pines Subdivision & Great Abaco Primary School

The Central Pines subdivision is on the left; the Great Abaco Primary School (**Location A,** where the author rode out the front side of the hurricane) is in the upper-right. This part of town is well above sea-level, so the destruction shown here is entirely wind damage.

Central Pines & Primary School: BEFORE

Central Pines & Primary School: AFTER

View C: Bahamas Government Complex & Mudd/Pigeon Peas

The Bahamas Government Complex (**Location B,** where the author moved to during the eye) is in the lower-left. A strong building on a hill high above sea-level, it survived the storm. The Mudd and Pigeon Peas are the densely-built areas just right of the image's center. These neighborhoods—low-lying and consisting of mostly substandard construction—were completely swept away by the storm surge.

Government Complex & Mudd: BEFORE

Government Complex & Mudd: AFTER

Video Footage

Everything described above can be seen in the author's 31-minute video summary of the event.

Find it on YouTube (https://youtu.be/DV-PLJq4HD4) or on the iCyclone Website (http://icyclone.com/chases/dorian-2019.html).

All the footage is timestamped in local time (EDT).

Questions or Feedback?

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