



Country Report from Bermuda for the 42nd Session of the WMO Regional Association IV Hurricane Committee

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1. Review of 2019 Season

After a couple of relatively quiet years with no real impacts, 2019 turned out to be quite a busy season once again, largely due to Hurricanes Humberto and Jerry in September. The season started early with eyes to the southwest in late May, as Subtropical Storm Andrea developed. However, Andrea only had a short lifespan (May 20th-21st), due to an increasingly hostile environment as it made its approach to Bermuda, and thus had very little impact on the Island with no tropical watches/warnings required.

Towards the peak of hurricane season, all eyes were trained on Hurricane Humberto, which was forecast to make a close pass to the northwest of Bermuda on September 18th-19th. A Hurricane Warning was issued at 6pm on September 17th. The track forecast turned out to be very accurate for Humberto. However, the intensity forecast was somewhat more challenging, due to an expanding wind field and a relatively unusual re-intensification to near category 4 status (110 knots) within a couple of hundred miles of Bermuda as it moved by to the north. The island bore the brunt of the southern eyewall of major Hurricane Humberto (category 3), which was both a strike and direct hit (as per NHC definitions). Although there was significant damage to vegetation and property, there was thankfully no loss of life. More details on this event are described in section 2.

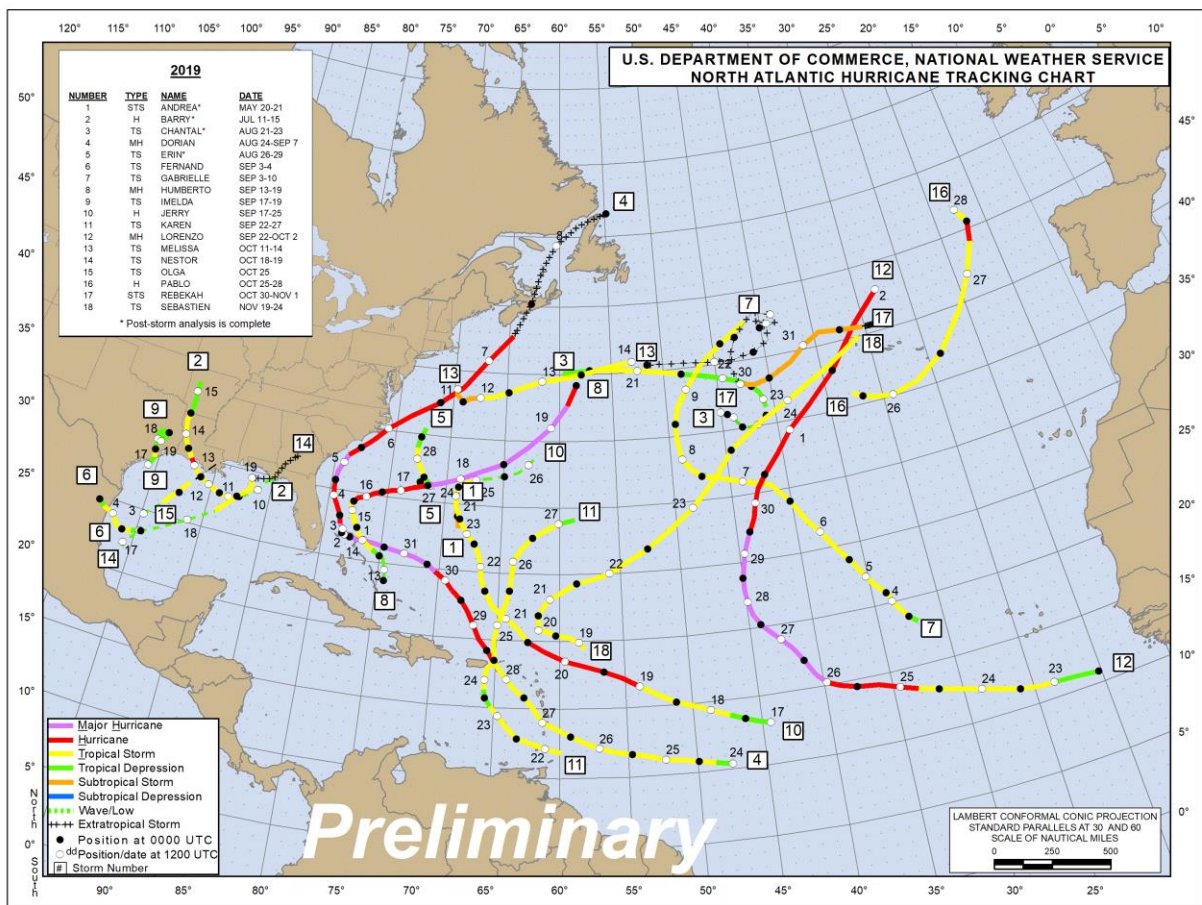
Close on the heels of Hurricane Humberto was Hurricane Jerry. Initial forecasts had Jerry making a close pass to the north of the island as a category 1 hurricane. However, as Jerry continued its approach from the southwest, it started to succumb to extra-tropical transition (increasing wind shear and dry air). Despite Jerry weakening to a Post-Tropical Cyclone on its final approach to Bermuda, due to the notable and very recent impacts of Humberto, including some properties losing parts of their roofs, the island remained on high alert for Jerry, and a Tropical Storm Warning which was issued at 9am on September 23rd remained in place. The island's only storm shelter, Cedarbridge Academy, also opened its doors for any vulnerable residents that needed it (e.g. the homeless and those who had lost roofs). As with Humberto, there were several Emergency Measures Organisation (EMO) meetings, as well as press conferences to keep the public informed. Thankfully, Jerry weakened below tropical storm force around 40nm to the west-southwest of Bermuda at 6pm on September 25th and the Tropical Storm Warning was cancelled. Impacts of the remnant low of Jerry to the Island were minimal, with winds barely gusting to tropical storm force, some rough seas outside the reef-line, and a relative lack of rainfall, with just an inch or so falling. Given the widespread impacts



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of Humberto less than a week earlier, the relative non-event of Jerry helped the island breathe a sigh of relief, and there was very little criticism in the evolving and less impactful forecasts of this subsequent tropical system.

Preliminary Atlantic Tropical Cyclone Tracks (source NHC) -





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2. Hurricane Humberto, September 18th-19th

Preparations –

Bermuda Weather Service (BWS) issued Threat status (system expected to come within 100 nautical miles of Bermuda within 72 hours) for this system at 6am on Monday 16th September. The official forecast and multi-model projections by this stage were relatively confident on a steady east north-eastward track of Humberto, passing Bermuda to the near north/northwest of the Island (within 100nm or so) later in the week. The intensity forecast, although perhaps not as confident as the track, still suggested that Humberto would remain a hurricane as it made a close passage by Bermuda sometime Wednesday 18th night into Thursday 19th morning.

In line with further watch and warning protocols, and the increasing likelihood of at least tropical storm force winds impacting Bermuda later in the week, a Tropical Storm Watch was issued at 6pm on Monday 16th. This was then upgraded to a Tropical Storm Warning at 9am on Tuesday 17th as the expectation of tropical storm force winds increased. During Tuesday 17th it became increasingly apparent through regular coordination calls with the hurricane specialists at NHC that Bermuda was going to have a significant hurricane impact from a major hurricane. As such, an additional Hurricane Watch was issued at 12noon on Tuesday 17th, and this was later upgraded to a Hurricane Warning at 6pm that evening. Essentially, the underlying reason for the increasing likelihood of hurricane conditions for Bermuda was because Humberto continued to intensify as it made its final approach towards the Island. In addition to this, likely due to some extratropical influences (e.g. baroclinic forcing in the right-rear entrance region of a strong jetstream wind maximum), the hurricane force wind field also continued to expand. The combination of these factors not only justified the Hurricane Warning, but also an earlier than initially expected onset time of tropical, storm and then hurricane force winds across the Island.

Dedicated stakeholder (e.g. airport and local Emergency Measures Organisation, also known as the EMO) briefings began on Monday 16th and ran through Wednesday 18th lunchtime, including a media/press conference for the public led by the Minister of National Security. Appropriate public messaging was also communicated via the Government's 'Tree Frog' app as well as the EMO's Emergency Broadcast Radio station, 100.1FM, which was activated later on Wednesday 18th. As part of the country's preparations, aside from the usual personal and business ones ahead of a hurricane impact, many boats/yachts were pulled out of the water, and all aircraft were cleared from the airfield during the NOTAM closure period from 3pm on Wednesday 18th (until an estimated time of noon on Thursday 19th). Several cruise ship call-ins were cancelled or re-routed elsewhere. A number of flights were also cancelled around the NOTAM airport closure period. Schools and businesses closed at midday on Wednesday 18th, with everyone encouraged to stay off the roads well before dusk that day. As for local public transport, the buses ran until 4pm on Wednesday 18th, whilst all ferries were cancelled for both Wednesday 18th and Thursday 19th. The Causeway, the only artery from the main Island to the airport, was officially closed to all but emergency vehicles at 7pm on 18th. The Royal Bermuda Regiment, which assists with recovery efforts, was embodied at 5pm Wednesday 18th. Ambulances were strategically assigned around the Island, whilst BELCO (local electricity company) staff were positioned in eastern, western, and central parishes. The country's only official storm shelter, Cedarbridge Academy, was also opened at 5pm on Wednesday 18th. The expectation was that businesses would begin to return back to



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normal later on Thursday 19th and into Friday 20th September, when schools would re-open assuming no significant damage.

The timeline of the issuance of BWS watches and warnings is detailed in the table below (all times are local):

Watch/Warning Type	Issuance Time	NHC Advisory #
Tropical Storm Watch issued	6pm Monday 16 th September	17
Tropical Storm Warning issued	9am Tuesday 17 th September	19A
Tropical Storm Warning & Hurricane Watch issued	12pm Tuesday 17 th September	20
Hurricane Warning issued	6pm Tuesday 17 th September	21
Hurricane Warning ended, Tropical Storm Warning issued	12am Thursday 19 th September	26
Tropical Storm Warning ended	3am Thursday 19 th September	26A

Onset –

Conditions started to deteriorate later on Tuesday 17th September, with steady pressure falls and increasing tropical moisture moving into the area. Showers became increasingly organized and heavy into the morning of Wednesday 18th, with widespread thunderstorm activity in concert with an active band of convection associated with Humberto. Thereafter, conditions tended to become drier with mostly isolated light shower activity (large dry slot was apparent on local radar imagery). However, winds really started to pick up in the afternoon of Wednesday 18th, with sustained south-southwesterly tropical storm force winds reaching the airport around 5pm. Sustained southwesterly storm force winds then arrived around 7pm with a period of sustained westerly hurricane force winds from about 8pm to 9pm at the airport. Elsewhere saw sustained hurricane force winds from around 7pm to 9:30pm (N.B. all sustained winds quoted use a wind averaging period of 10mins – therefore, if 1min averaging period is used the onset of sustained hurricane force winds across the west end of the Island could be brought forward to around 6:30pm). Peak winds affected the Island from around 8-8:30pm, when 82knots was recorded at an offshore site to the north of Bermuda called the Crescent (located on a main shipping channel). If this 10min averaged wind speed is converted to 1min averaging, then the figure is nearer 93knots, giving parts of Bermuda a period of sustained 1min averaged winds speeds near category 3 status. The highest gust at the surface was 113knots recorded at the Crescent. However, elevated parts of the Island recorded notably highest gusts, including 125 knots at MAROPS in St George’s at around 290ft, and 167knots (likely an



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overestimate due to wind flow over the building accelerated by the Bernoulli effect) at an unofficial sensor at Commissioner's House, Dockyard, with an elevation of around 150ft. The lowest pressure recorded was 970.4mb at the Pearl Island sensor in the Great Sound at around 8:30pm. Conditions thereafter improved steadily as the eye of Humberto passed around 67nm to the north-northwest of Bermuda around 9pm, and the Hurricane Warning was downgraded to a Tropical Storm Warning by midnight.

Other meteorological impacts included a well forecast storm surge by the NHC storm surge unit, which peaked at 2-3ft at 9pm at the Esso Pier tide gauge on the north side of St George's. The NOAA OPC wave analysis recorded maximum seas around Humberto of 48ft at 9pm (00z), with a maximum of around 42ft likely impacting the northern marine area of Bermuda (marine area extends 25nm off-shore). During the peak of the hurricane force winds, there were some sudden and dramatic pressure changes of several millibars in a few minutes, and this likely contributed to the very turbulent nature of the wind at that time. This period was also coincident with most of the damage across the Island, which included roof damage, vehicle damage, boat damage and general Island infrastructure damage, including power lines and utility poles. Damage to vegetation was also widespread, with many trees felled (see further details in next section). Coincident with the sudden pressure changes were also fluctuations in air temperature, which temporarily cooled to around 22C/72F.

It is interesting to note that Humberto was actually intensifying as it made its close passage by Bermuda, despite an increasingly hostile wind shear environment. A solid category 3 hurricane with 105g130kt winds increased to near category 4 at 3am on Thursday 19th with winds of 110g140kt when around 170nm to the north-northeast of Bermuda. Despite Humberto's relatively north location for an intensifying major hurricane, a couple of intensely debated extra-tropical transition-related reasons were put forth. One was the influence of a rear right jet entrance, the other was a sting jet type influence with an incursion of dry air from mid-levels (evidenced by the water vapour imagery at the time). Another reason Bermuda saw such damaging winds was that Humberto was undergoing an eye wall replacement cycle (ERC) as it approached Bermuda, ultimately putting Bermuda under the southern eye wall for a short period of time (as evidenced by radar imagery before the radar went offline). The NHC's tropical cyclone report for Hurricane Humberto goes into further detail with respect to its rather unusual intensification at such a northerly latitude - https://www.nhc.noaa.gov/data/tcr/AL092019_Humberto.pdf

Damage Impacts & Recovery –

As mentioned above, damage was extensive, and mostly occurred during the late evening around the closest point of approach. The full extent of the damage became apparent at dawn on Thursday 19th September, with staff members of Bermuda Weather Service going outside to survey the damage around the compound. Much of the boundary fencing came down, the GOES-16 satellite receiving dish at the front of the building was destroyed, whilst the balloon launch deck at the rear was completely pulled off its foundations and moved a considerable distance to the east. Even vehicles in the parking lot were moved, one by tens of feet due the immense power of the westerly hurricane force winds, noting that this area is very exposed to westerlies which are funneled to the north of the air traffic control tower. Two vehicles sustained significant damage, one having damage to its front bumper, the other losing its windshield (perhaps popping out of its frame due to



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the sudden pressure fluctuations) which blew away so far it took some time to find. There was also damage to various antenna, and the reason the radar imagery was lost towards the height of Humberto was because the access hatch to the radome popped open, which automatically shuts the system down as a safety precaution. Across the Island, damage to buildings, vehicles, boats and infrastructure was extensive, including very significant vegetation damage. Most notable was the extensive damage to roofs, especially towards the west end of the Island, where Somerset Police Station lost part of its roof. The number of buildings damaged likely ran into the hundreds and damage estimates were comfortably in the tens of million of dollars category.

With many power and utility poles downed, electricity was cut off to as many as 80% of BELCO (local electricity company) customers at the peak of the outage. Other notable damage included significant damage to one of the jetways at the new airport terminal building (scheduled for opening in summer 2020). A government boat also came off its mooring in the east end and was lost at sea, sunk or drifting. A shipping container was also blown into the sea at Dockyard and was never found, presumed sunk. During daylight hours later on Wednesday 18th a mature coconut palm tree in Barr's Bay Park, Hamilton, snapped in two like a tooth pick. This event was filmed and went viral on social media. A further video of a roof blowing off a building in the east end also went viral. Although hurricane force winds were not impacting the Island at the time, it is possible some localized tornadic activity affected some areas, especially considering the Island was in the tornado risk zone at the time (right forward quadrant of Humberto). The main take away from Humberto was that the Hurricane Warning was taken seriously by the community, and it was very fortunate there was no loss of life or life-threatening injuries. One of the few serious incidents involved a man who chose to remain on his moored yacht in the Great Sound area. It came off its mooring, and the man almost abandoned ship during the height of the storm. Thankfully, it wrecked on an Island in the Sound and local residents came to his rescue, notably wearing helmets at the time, to protect themselves from flying debris.

Recovery was swift, with the Bermuda government very keen to get the Island back up and running again. With plenty of practice in recent years (e.g. Hurricanes Fay, Gonzalo and Nicole), all the various recovery agencies came together and quickly addressed the extensive Island-wide damage. The Royal Bermuda Regiment worked in collaboration with the Department of Parks and Works & Engineering (part of Ministry of Public Works) to begin to clear away debris from early morning on Thursday 19th September. Their main priorities were to clear the roads, assess bridges etc., so that the main thoroughfares could be open to the public as quickly as possible. The airport buildings suffered only minor damage, but the surrounding security fencing was extensively damaged. Fortunately one of the main local fencing contractors addressed this damage as a matter of priority, and this enabled the airport to re-open during the afternoon hours of Thursday 19th, as stated in the NOTAM. BELCO quickly repaired most of their main electricity supply lines, allowing much of the country to return to power by the weekend. A lot of businesses were able to reopen on Friday 20th, but many schools remained closed, due to building assessments having to be made as well as peripheral issues such as lack of power, clean/running water etc. The many buildings that lost part of their roofs were provided temporary cover with the use of tarpaulin. Given Bermuda's general resilience to hurricanes and the prompt and well-practiced preparation and recovery efforts, the majority of the Island got back on its feet surprisingly quickly, given a direct hit from an intensifying category 3 hurricane. However, isolated power outages remained for many more days to come, and some minor roads and the railway trail remained blocked by trees for up to several weeks.



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Communications –

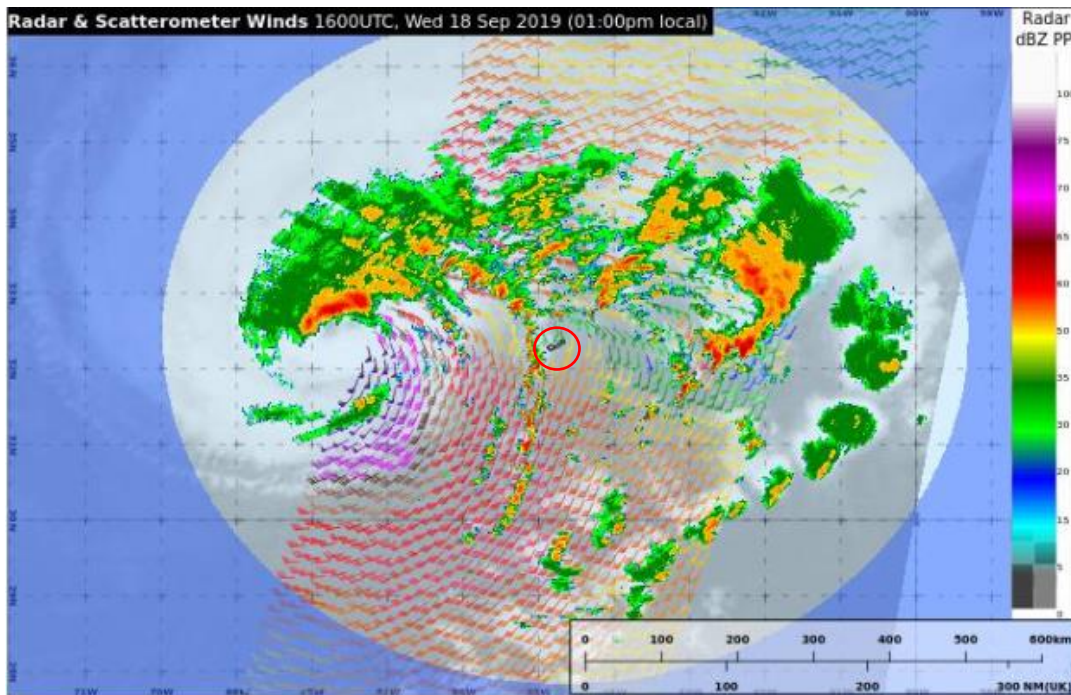
The Bermuda Weather Service, in collaboration with the Government's Disaster Risk Reduction Mitigation Team (DRRMT), carry out a Hurricane Preparedness Week every year around the official start of the Atlantic hurricane season. Various community outreach events are planned, including briefings, dedicated pages on the weather service's website and radio broadcasts. This reminds people to prepare for the season ahead, but also how the weather service communicates in concert with the Government's Emergency Management Organisation (EMO). In addition, a further event is held in August, ahead of the height of the season for Bermuda, for the EMO and its extended members, when the Bermuda Weather Service Director provides the latest updates on the seasonal forecast, as well as another reminder on communication. This season, in addition to the standard weather service products (e.g. Hurricane Warning) which are routinely broadcast on the internet and local cable TV weather channels, and then beyond via radio and the local TV news channel, communication to the public was also assisted with a new Government cell phone app called 'Tree Frog', which sends out amongst others, severe weather alerts to the members of the public who sign up to the app (noting it is free on iOS and Android formats). There was also a major press conference around midday on Wednesday 18th September, providing the country with all the latest details (e.g. transport, business & school closures etc.) just a few hours ahead of the height of Humberto. During the event itself, noting that many people would likely lose power (which they did), regular weather and peripheral updates (e.g. power outages) were made on the Government's Emergency Broadcast Radio (EBR) facility, 100.1FM. Hourly interviews were conducted 'live' with the weather service, in order to communicate the latest weather information to the public. This EBR facility was used during Hurricane Nicole and proved to be very popular and well received by the public. Once again with Hurricane Humberto, it was a resounding success in terms of up to the minute communications. Finally, taking advantage of cell phone technology, two WhatsApp groups were set up, one for the Bermuda Airport Authority and one for the EMO. These helped to streamline the steady flow of information to various key personal at the airport as well as the EMO and its numerous members.



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Supporting Imagery –

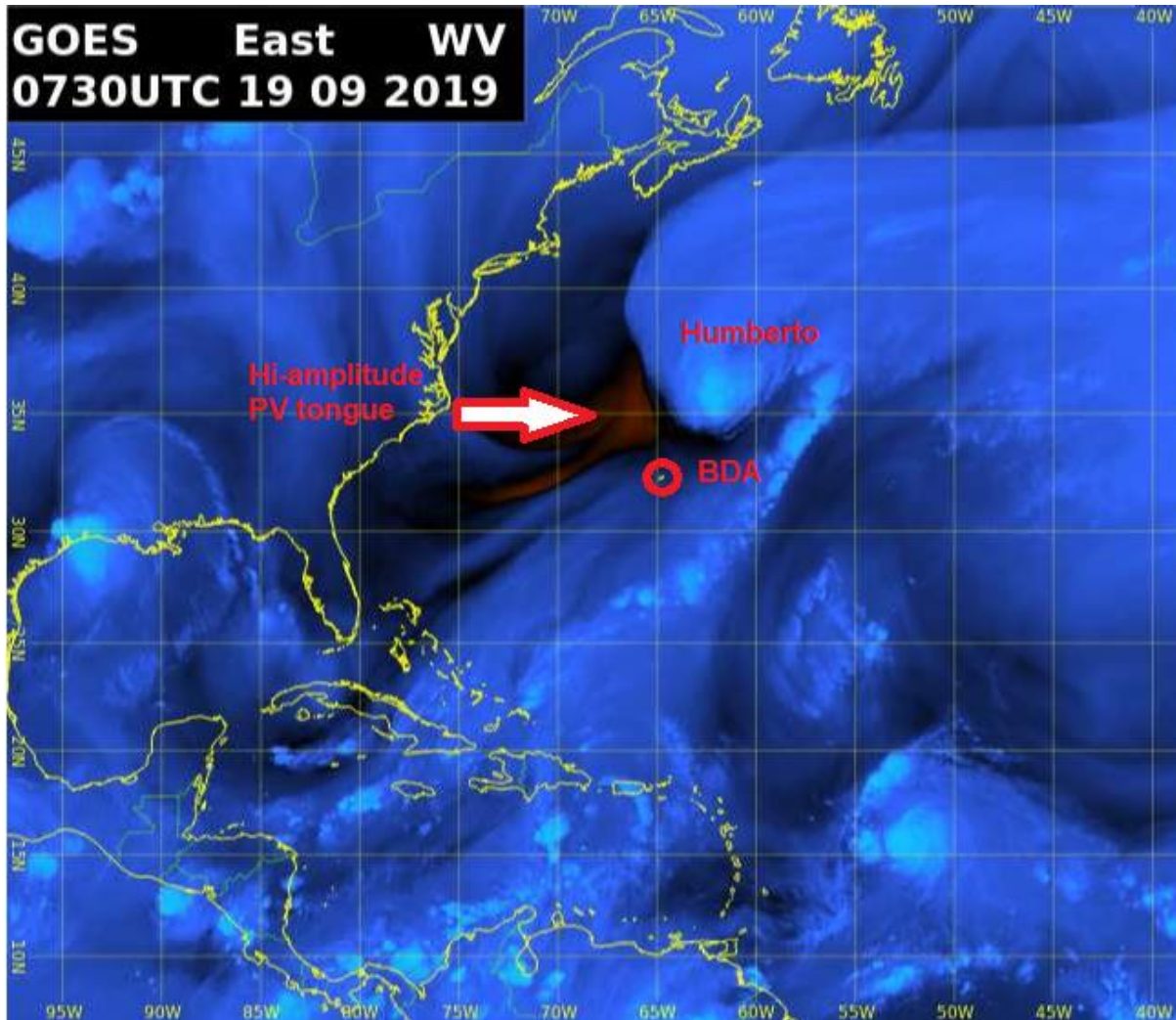
Combined radar/satellite/scatterometer data during Humberto's final approach (BDA in centre of image) –





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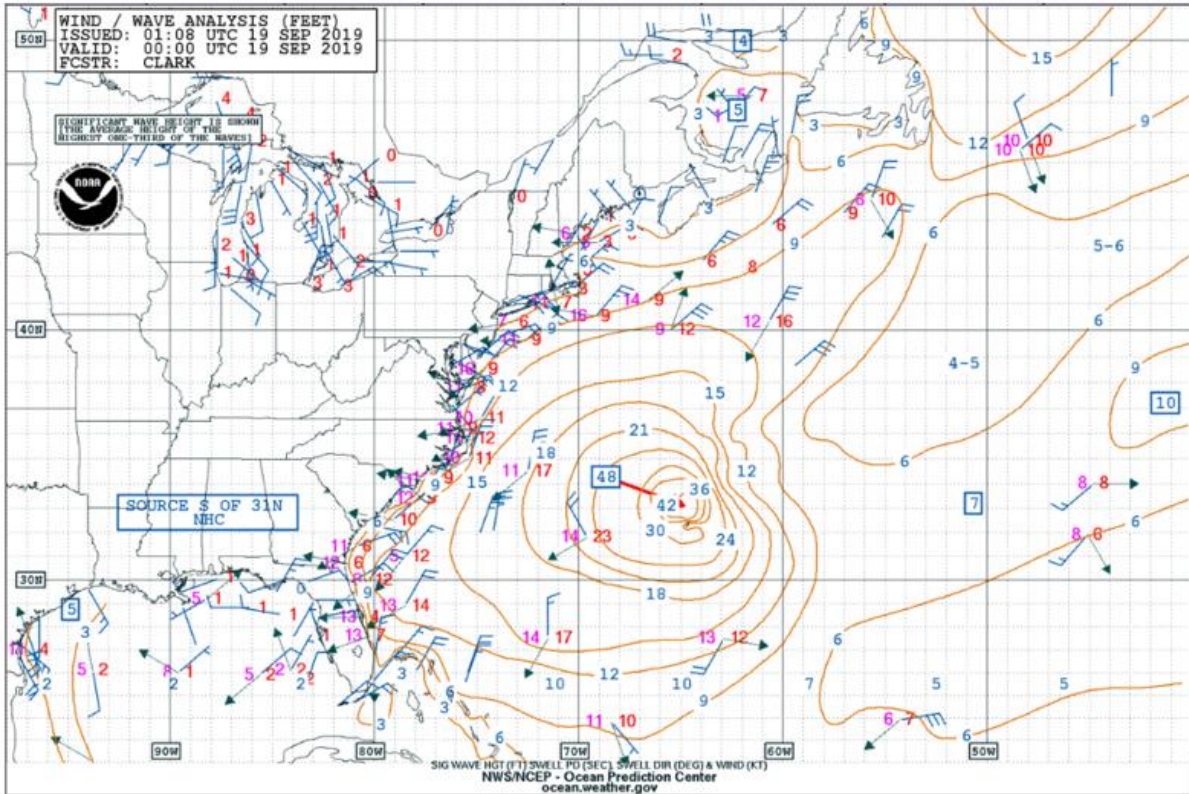
Water Vapor Image showing high amplitude PV tongue working into rear of Humberto early on 19th September –



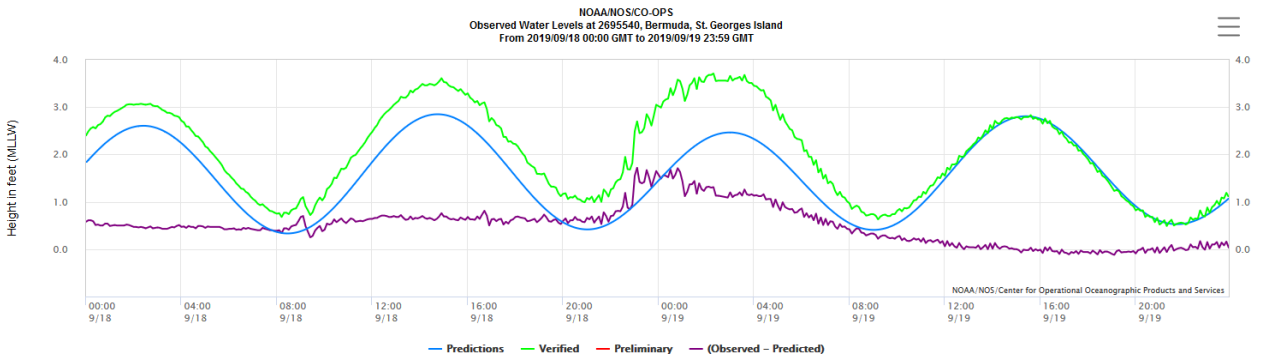


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NOAA OPC Wind/Wave analysis –



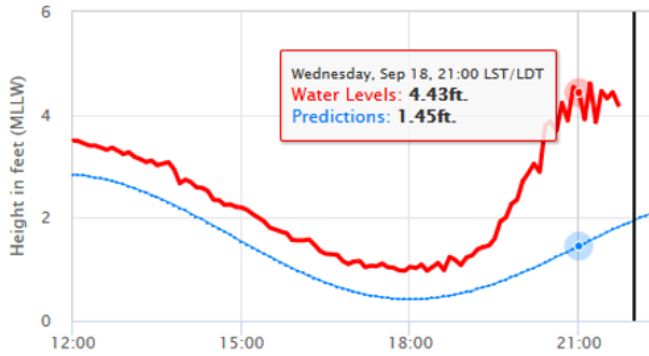
NOAA Esso Pier Tide gauge data (highlighting towards 2ft storm surge on north side of St. George's) –





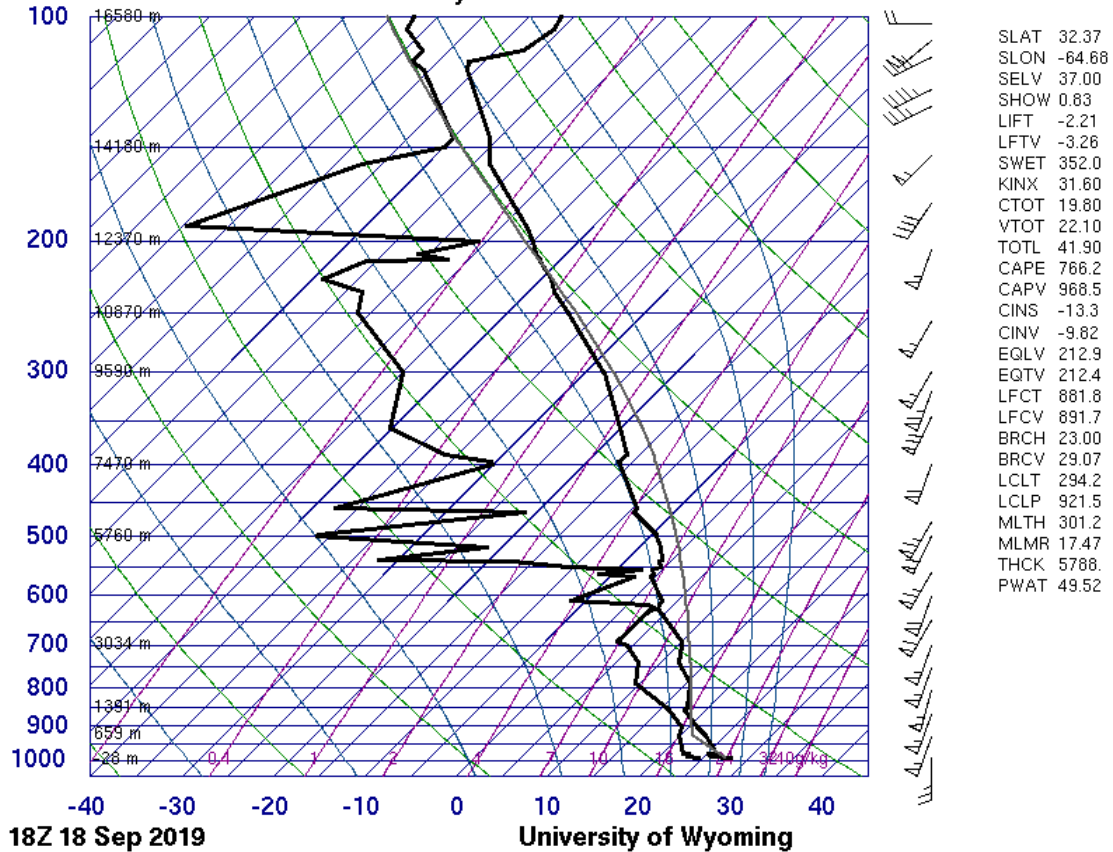
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Potential storm surge of near 3ft –



Skew-T diagram from 18Z radiosonde launch as Humberto made its final approach –

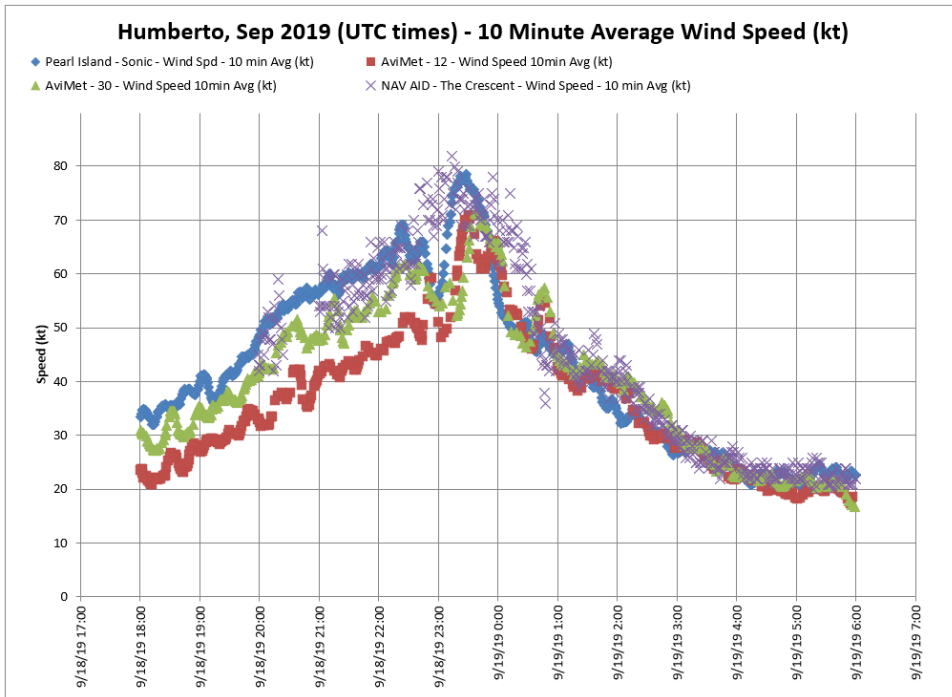
78016 TXKF Bermuda Nvl Stn Kindley



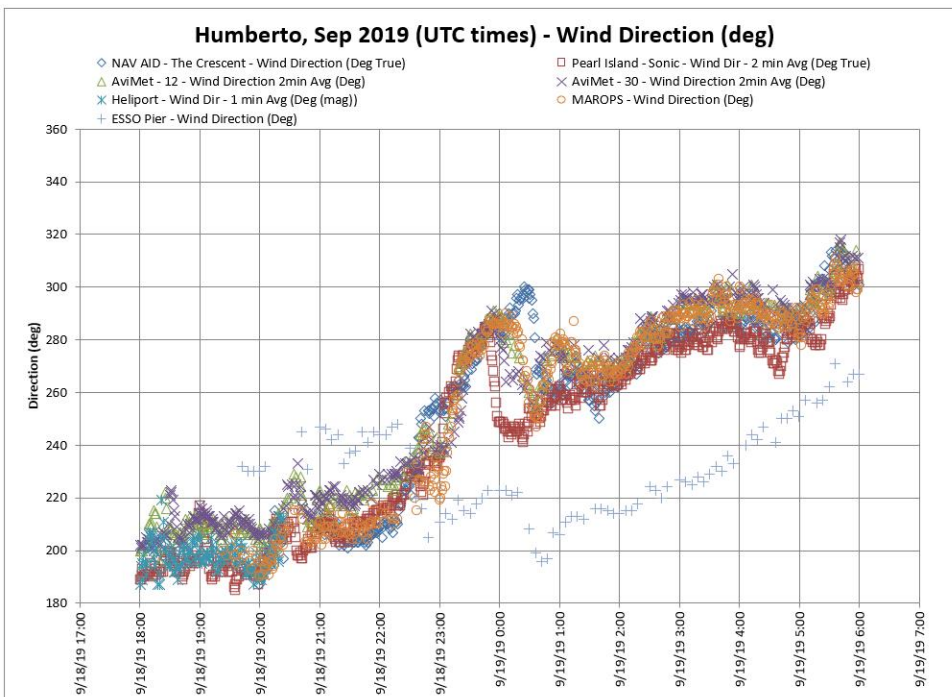


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10min average wind speed trace for various low level (near sea level) sites –



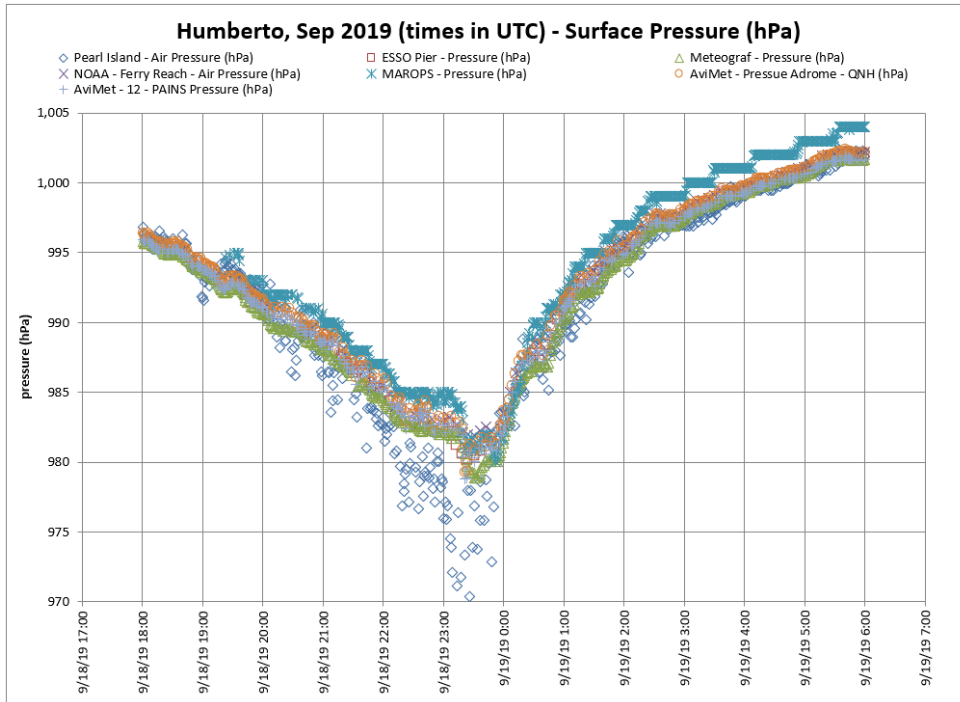
Wind direction trace from multiple sites –



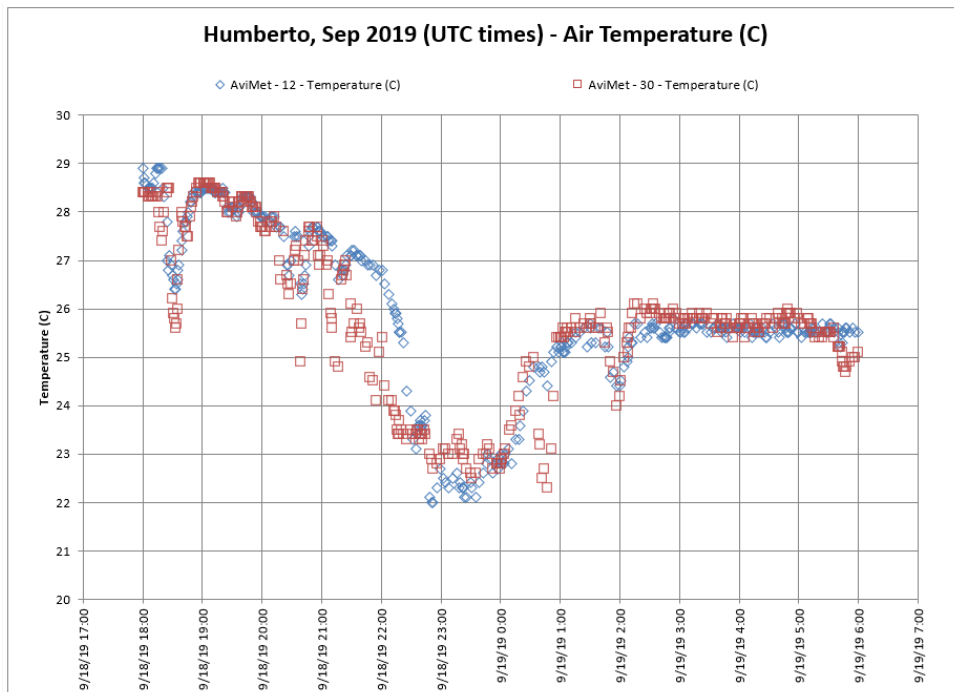


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Surface pressure trace for multiple sites –



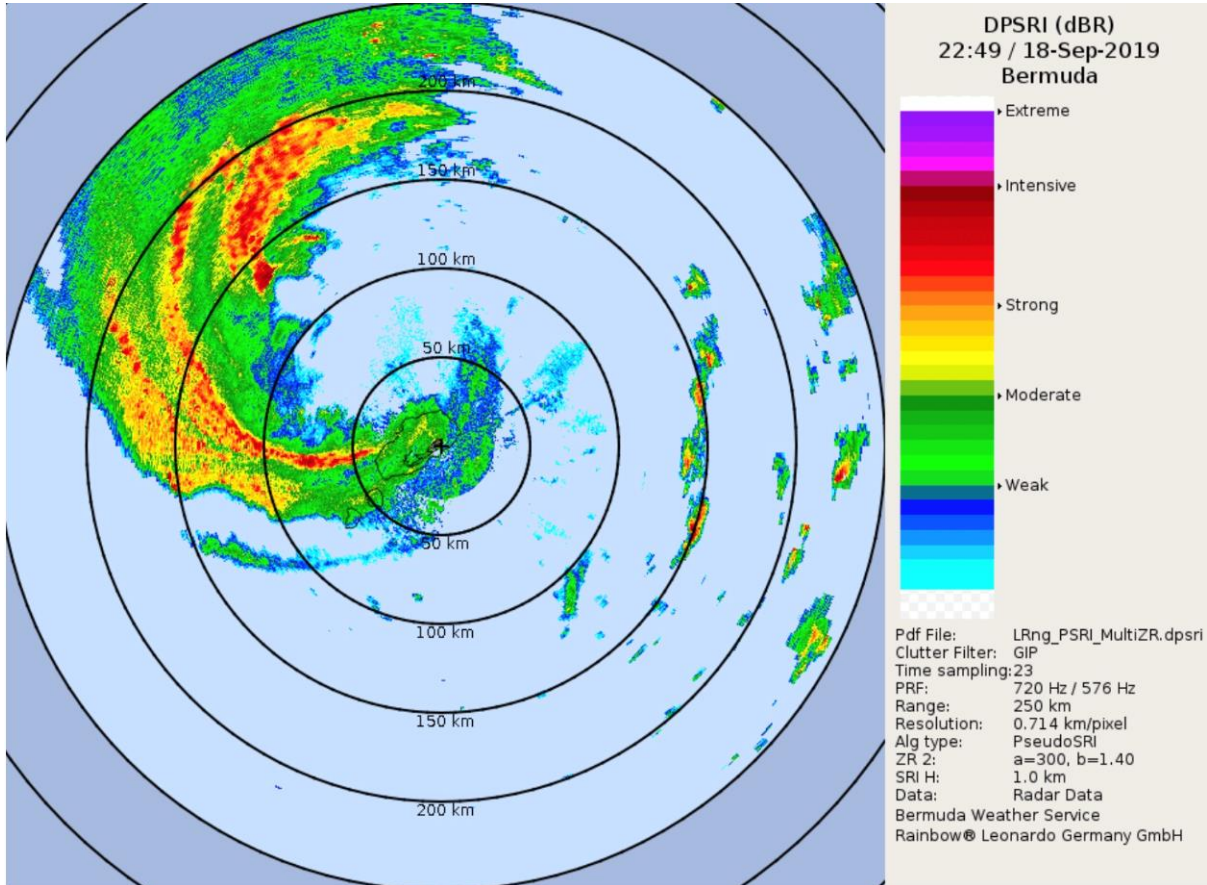
Air temperature trace from airfield AWOS sensors –





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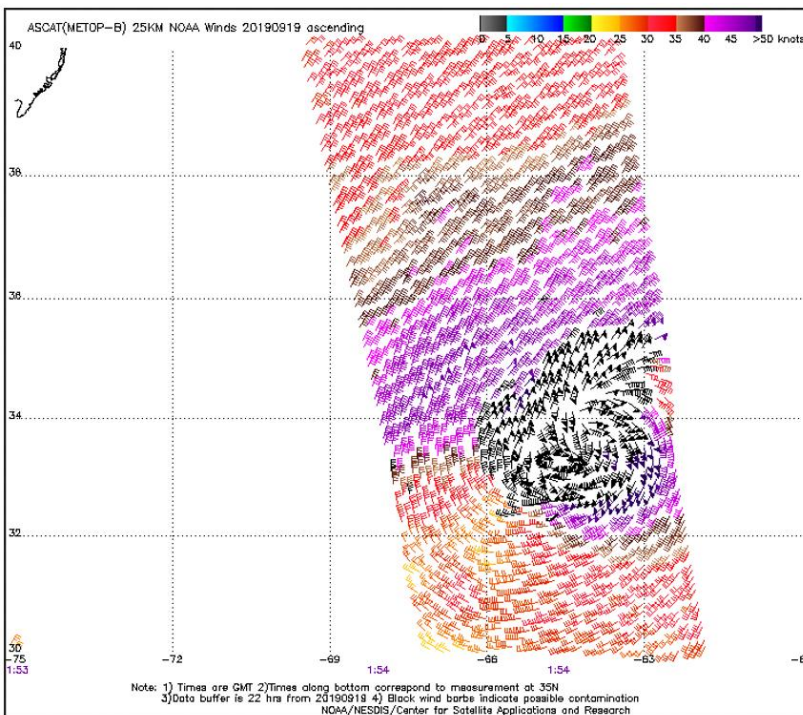
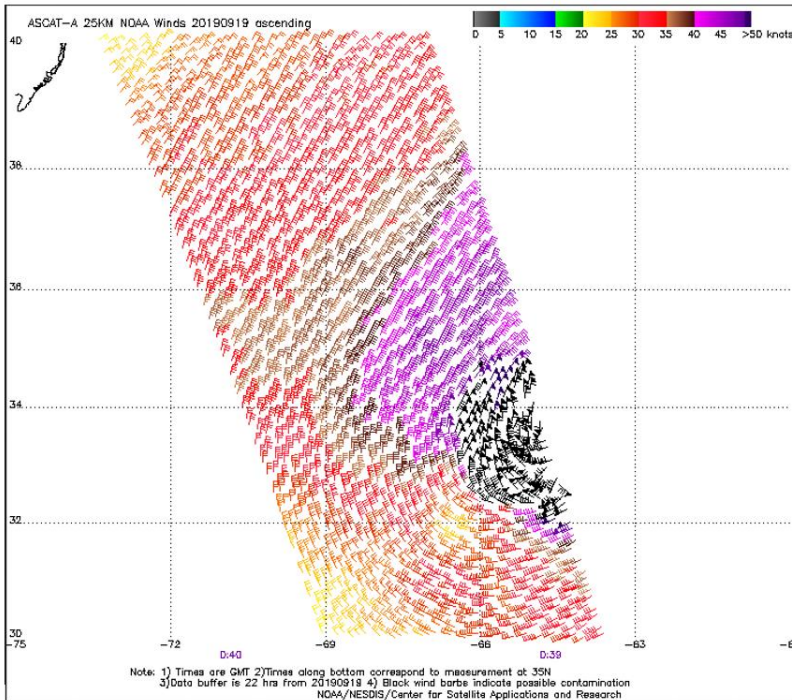
Potential eyewall replacement cycle (ERC) just ahead of eyewall impact on Bermuda –





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Ascats passes –





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3. Summary Table – 2019 Tropical Systems that affected Bermuda

Storm Name	Month & Date(s)	Watch/Warning Issued for Bermuda	Maximum Wind Speed at LF Wade (10min averaging)	Maximum Wind on/near Island	Significant Surge, Swell, Rainfall &/or Flooding	CPA & other notes	Verification
Sub-Tropical Storm Andrea	May 20 th -21 st	Potential Threat Small Craft Warning (verified) Thunderstorm Advisory (didn't verify)	22G26KT	Nil sig	Nil sig <6ft seas	13UTC 22 May 50nm SSE (noting that it had gone post-tropical by this time)	All models had a low to the SW developing (to a greater or lesser extent). Indications for a small window of opportunity to attain (sub) tropical characteristics were apparent (cyclone phase space diagrams). However, conditions were correctly forecast to become less conducive for development as low approached BDA – including dry air/wind shear in concert with approaching cold front, cooling SSTs.
Hurricane Dorian	September 6 th -8 th	No Threat Small Craft Warning mainly for seas (verified), briefly for winds on Saturday 7 th	19G24KT	Nil sig	Up to 13ft with long period W/NW swells	03UTC 7 September 446nm NW	Forecasts indicated a distant western passage up the US eastern seaboard, with long period swells approaching the island the weekend of the 6 th -8 th September
Hurricane Humberto	September 17 th -19 th	Threat TS Watch 6pm Monday 16 Sept TS Warning 9am Tuesday 17 Sept Hurricane Watch Hurricane Warning	71G101KT	80G125KT at MAROPS Unofficial gust of 167KT at Windguru site, Dockyard, Comms House	3ft of surge as forecast by NHC. Seas in excess of 40ft outside the reef. Generally 2-4 inches, locally 5.	00UTC 19 September around 70nm to NNW, still intensifying from 105KT cat 3 to 110KT cat 3, only 3KT off cat 4.	Models – some initial difference in model timing and track, although started to consolidate Monday into Tuesday. Challenges with expanding wind field due to tropical transitioning and interaction with a PV tongue, right jet entrance etc.



							Possible sting jet-like feature. Also challenges with forecasting expanding southern eyewall into our area which produced most damaging winds around 8-10pm.
Hurricane Jerry	September 24 th -25 th	Threat TS Watch midnight 0001hrs Monday 23 Sept TS Warning 9am Monday 23 Sept	28G34KT day before 25G31KT day of	28G34KT at MAROPS	12-15ft max seas, negligible surge	Almost overhead, just to NW of Island. As winds dropped out near centre mist and fog developed for a time on night of 25-26 th September, Fairly dry system (1inch or so) due to being sheared and going post-tropical	Challenging as well, due to slowing, weakening and transitioning to post-tropical/remnant low status. However, track forecast was very good.
Hurricane Lorenzo	September 28 th for developing long period swells	Small Craft Warning for rough swells (9ft+) issued Friday 27 th September at 5:30am beginning evening of 28 th September			9ft+ seas developed Saturday 28 th night into Sunday 29 th September, peaking at around 11-12ft	Around 1120nm to E at 6pm Sunday 29 th September	Models (UKMO) generally did well on forecasting the long period (rough) easterly swells

Compiled by J Dodgson, BWS Director, 21st February 2020