

PRELIMINARY REPORT ON HURRICANE JOAQUIN FROM BERMUDA - FOR THE 38TH SESSION OF THE WMO REGIONAL ASSOCIATION IV HURRICANE COMMITTEE.

Hurricane Joaquin, October 4th-5th

Bermuda Weather Service (BWS) began issuing tropical update bulletins and emails for newly formed Tropical Depression 11 as of Monday 28th September. By Tuesday it had intensified into Tropical Storm Joaquin, the 10th named storm of the season, and by the early hours of Wednesday it became Hurricane Joaquin, the 3rd hurricane of the season.

With some long range projections suggesting Joaquin could track towards Bermuda, BWS communicated directly with representatives from the Bermuda Emergency Measures Organisation (EMO) on Wednesday 30th September regarding the possible impacts of Hurricane Joaquin on Bermuda during the weekend ahead. At that stage, the unusually high uncertainty in the track forecast was emphasised, as well as the need to regularly monitor the progress of this hurricane.

During subsequent days, the model guidance in concert with the NHC advisories, steered the hurricane track forecast increasingly away from any US East Coast landfall (the original area of concern) and well into the West Atlantic, with increasing confidence on a near west passage past Bermuda later in the weekend. This signal began to be represented in earnest by the NHC advisories as early as first thing Friday 2nd October. In addition, this altered track forecast fell in line with a steadfast ECMWF track forecast, which remained fairly consistent on a passage to the west of Bermuda through the period (not dissimilar to the Hurricane Sandy forecast back in 2011). With the increase in confidence of some level of impact on Bermuda, the EMO called for daily briefing updates on Friday 2nd and Saturday 3rd October.

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

Status/Watch/Warning Type	Issuance Time	NHC Advisory #
Potential Threat	1800hrs Thursday 1 st October	16
Threat & Tropical Storm Watch issued	1800hrs Friday 2 nd October	20
Tropical Storm Warning & Hurricane Watch issued	0001hrs Saturday 3 rd October	21
Hurricane Warning issued	0001hrs Sunday 4 th October	26
Hurricane Warning ended, Tropical Storm Warning issued	0300hrs Monday 5 th October	30A
Tropical Storm Warning ended	1500hrs Monday 5 th October	32A

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During Saturday morning, around 1100hrs local, a text message alert was sent out to cell phone users by the local cell phone providers, Digicel and Cellular One. The alert emphasised that a Hurricane Watch had been issued, and that all hurricane preparations should be completed by Saturday night.

In addition to this, a NOTAM was prepared for LF Wade International airport, effectively shutting down airport operations as of 1600Z or 1300hrs local time on Sunday 4th October. The estimated re-opening time was 1300Z or 1000hrs the next morning.

Conditions began to significantly deteriorate Sunday afternoon as Joaquin made its final approach to the near west of Bermuda as a strong category 2 hurricane. As forecast, the worst conditions were late evening into early Monday morning, with Joaquin's closest point of approach approximately 59 nautical miles to the west-northwest of Bermuda at 2100hrs Sunday evening. This peak in the poor conditions was somewhat extended due to Joaquin making close passage both to the west and then north of Bermuda. The hurricane steered bands of rain and showers across the area, with some evidence of potential embedded tornadic activity in both the radar imagery and weather balloon/radiosonde data. The NHC broached this subject with BWS forecasters during Sunday afternoon, after their hurricane specialists had some discussion with the NOAA Storm Prediction Center's (SPC) specialists in Norman, Oklahoma. As a consequence, a clause relating to the possibility of embedded tornadoes was added to the NHC Public Advisory. Despite fairly strong evidence in the data, there were no confirmed reports of land-falling tornadoes in association with Joaquin. However, it is not to say that tornadoes may have occurred over the open ocean.

With regards sea state, levels had been elevated since as early as Wednesday 23rd September, due to east and southeasterly swells generated initially by Tropical Storm Ida to the distant southeast, and then a strong isobaric gradient caused by strong high pressure to the northeast and Hurricane Joaquin to the distant southwest. Seas, swells and surf peaked during the night of Sunday 4th into the morning of Monday 5th October, with the NOAA Ocean Prediction Center's (OPC's) sea state analyses estimating 30ft plus seas across the Bermuda area.

As for wind speeds, the Bermuda Weather Service automated weather observing system (AWOS) network was severely depleted ahead of the onset of the Hurricane. Therefore, only a limited dataset was available. This included data from anemometers on the airfield at LF Wade International Airport, as well as data from RCC Bermuda Radio located at Fort George, St George's, and from a relatively new off-shore sensor located at the Crescent on the North Channel.

With respect to the airport, the onset of tropical storm force winds (34 knots or more) was around 1130hrs on the Sunday. These tropical storm force winds continued for over 24 hours and finally ceased at around 1400hrs on Monday afternoon, a little later than initially forecast. The delay in tropical storm force wind cessation instigated the continuation of the tropical storm warning until 1500hrs on Monday (see previous

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table). Strongest winds during the whole event were realised during the latter part of Sunday evening, with the airport reporting mean winds speeds into the storm force category (48 knots or more) for a time, with gusts very near hurricane force (64 knots or more). The strongest gust recorded across the limited observational network was at the most exposed/elevated Bermuda site of RCC Bermuda Radio at Fort George, where a gust of 100 knots was recorded. This site also experienced a period of sustained category 1 hurricane force winds. Note that elevated winds at this location are not unusual, with Bermuda Radio regularly recording the highest wind speeds in extreme wind events.

Finally, with regards to surface pressure, the lowest values recorded across the observational network were all very similar at around 990mb or 29.24inches.

A table summarising wind speeds follows:

Reporting station	Speed	Time	Elevation of station
Airport (10min averaging period)	49kt gust 63kt	2011L/2205L for mean 2007L for gust	Approx. 40ft
RCC Bermuda Radio (1min averaging period)	80kt gust 100kt	Around 2200L	Near 290ft
Crescent – North Channel marker (1min averaging)	55kt gust 69kt	2254L	Near 20ft

Preparations –

As for preparations ahead of the impact, the Island was well prepared, thanks to timely watches and warnings from BWS, as well as concurrent preparedness advice from the Emergency Measures Organisation (EMO) and their associated agencies that was transmitted via various media channels, including television, radio, cell phones, newspapers and online, including BWS, EMO and other social media conduits.

Once again (as last year with Hurricane Gonzalo) social media played a major role in communicating information to the community. The BWS Facebook page received hundreds more 'likes' during the Hurricane Joaquin event, and the organic reach of the posts made on Sunday 4th October was almost 50,000 people.

As part of the EMO's preparation, the Bermuda Regiment was embodied and put on standby in order to help expedite recovery efforts once conditions started to improve. Not only were airport operations effected, but also cruise ship visits and local transport, both of which suffered cancellations.

One unexpected benefit of the onset of Hurricane Joaquin was a surge in community interest and donations to the recently wound down VSB radio stations company, which was able to resurrect some of its services in order to broadcast the latest important updates on Hurricane Joaquin. Indeed, during the height of the storm,

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VSB were able to maintain their 1450AM GOLD radio station broadcast, despite most other broadcasters temporarily going off air.

Damage impacts –

With regards damage impact, the Island managed to escape relatively unscathed (significantly less impact than 2014's Hurricanes Fay & Gonzalo), thanks in part to the core of strongest hurricane force winds (eye-wall) remaining offshore to the west of the Island, and also due to suitable preparation and the resilient infrastructure of the Island. There was certainly some damage to vegetation, but this was mostly downed branches rather than downed trees. Last year's hurricane likely cleared away much of the 'dead wood' and rains had not been as prolific this year leading up to Joaquin. These drier conditions would have contributed to a more resilient root structure, further limiting any tree felling. Despite generally limited damage to buildings, the National Museum at Dockyard (in the West End) once again sustained some damage to its roof structure that was still undergoing renovations from the previous year's hurricane impacts. Storm surge was minimal, and any effects would likely have been limited by the fact that the maximum storm surge occurred around the time of low tide (2114hrs on Sunday evening), thus helping to offset any surge inundation impacts.

According to local online news media, Bernews (<http://bernews.com/>), the Bermuda Fire and Rescue Service answered a total of 37 emergency calls. Despite the relatively minimal impacts, residents did sustain quite extensive temporary power outages, with as many as 15,000 BELCO customers off-line during the height of the hurricane. In addition, out of an abundance of caution, the Causeway was closed to all public traffic from late Sunday afternoon until late Monday morning, when it was re-opened upon a safety inspection assessment by engineers. Note that a western section of the Causeway was initially only open to one-way traffic for a couple of days, as some minor wall damage, not directly related to Joaquin, was repaired.

Despite some impacts to infrastructure and business into Monday morning, by afternoon it was business as usual for much of the Island, including the airport, with power outages generally being addressed very promptly. Thankfully, no significant injuries or loss of life were reported.

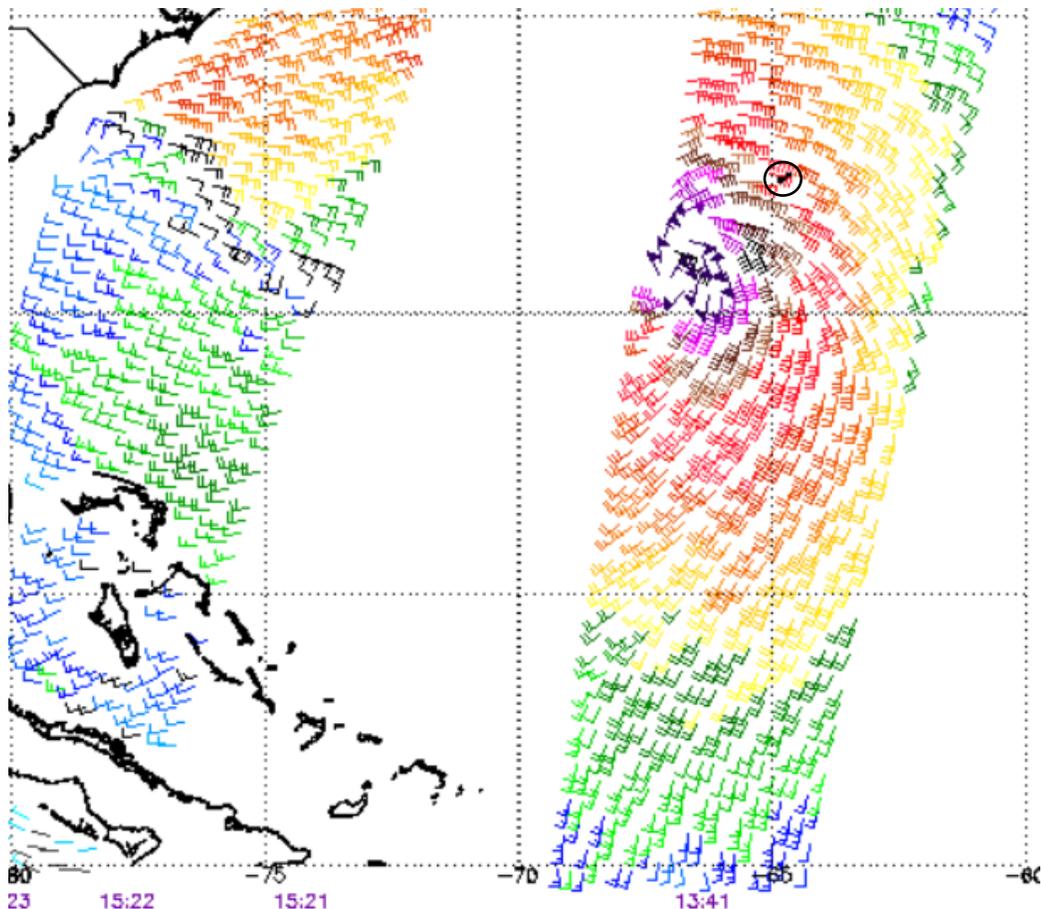
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Supporting imagery

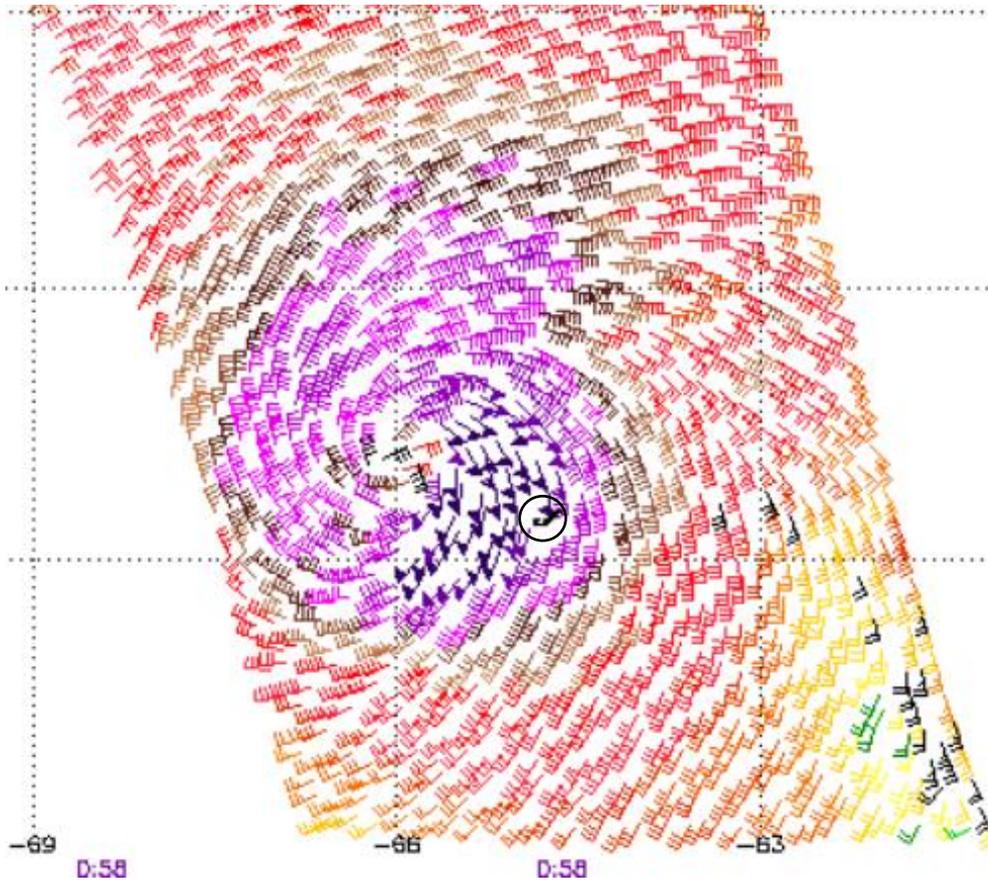
Satellite derived wind images –

Ascat satellite overpass, 50km resolution, at 1341Z on the 4th showing the circulation of Hurricane Joaquin just to the southwest of Bermuda (circled in black) – the pass shows the core of strongest winds skewed towards the east of Joaquin's centre:



A further higher resolution Ascat image, 25km, at 0058Z on the 5th clearly shows the outerband of 50 knots winds barbs fringing the Island (note that stronger hurricane force winds would have been evident within the area of 50 knots wind barbs just to the west of Bermuda):

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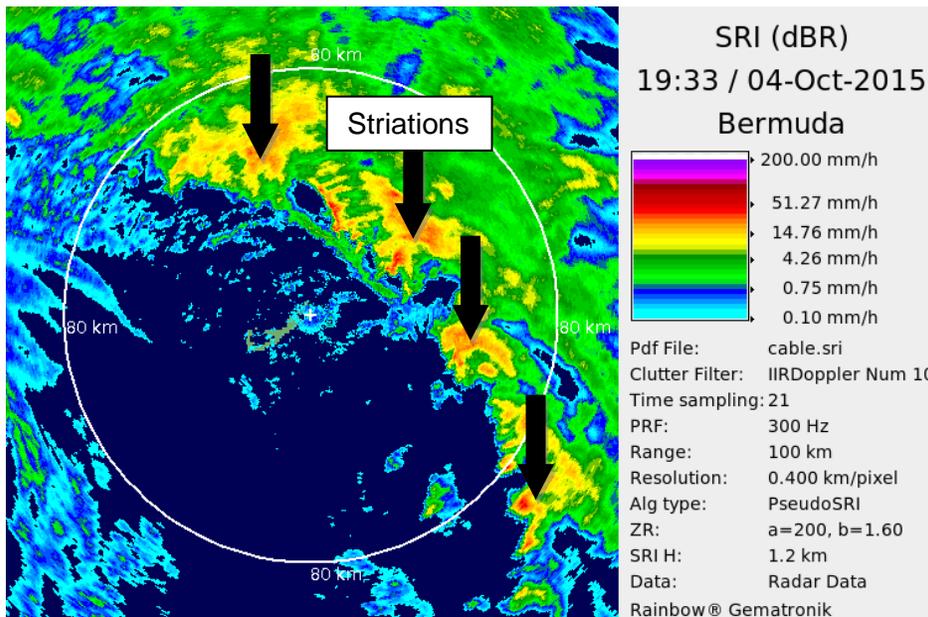


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Radar imagery –

Evidence of meso-vortices (potential tornadic activity) in the radar signature – the striated areas of deep convection (brighter colours) towards the north and east of the Island, northeast of the centre of Joaquin, just off the image:



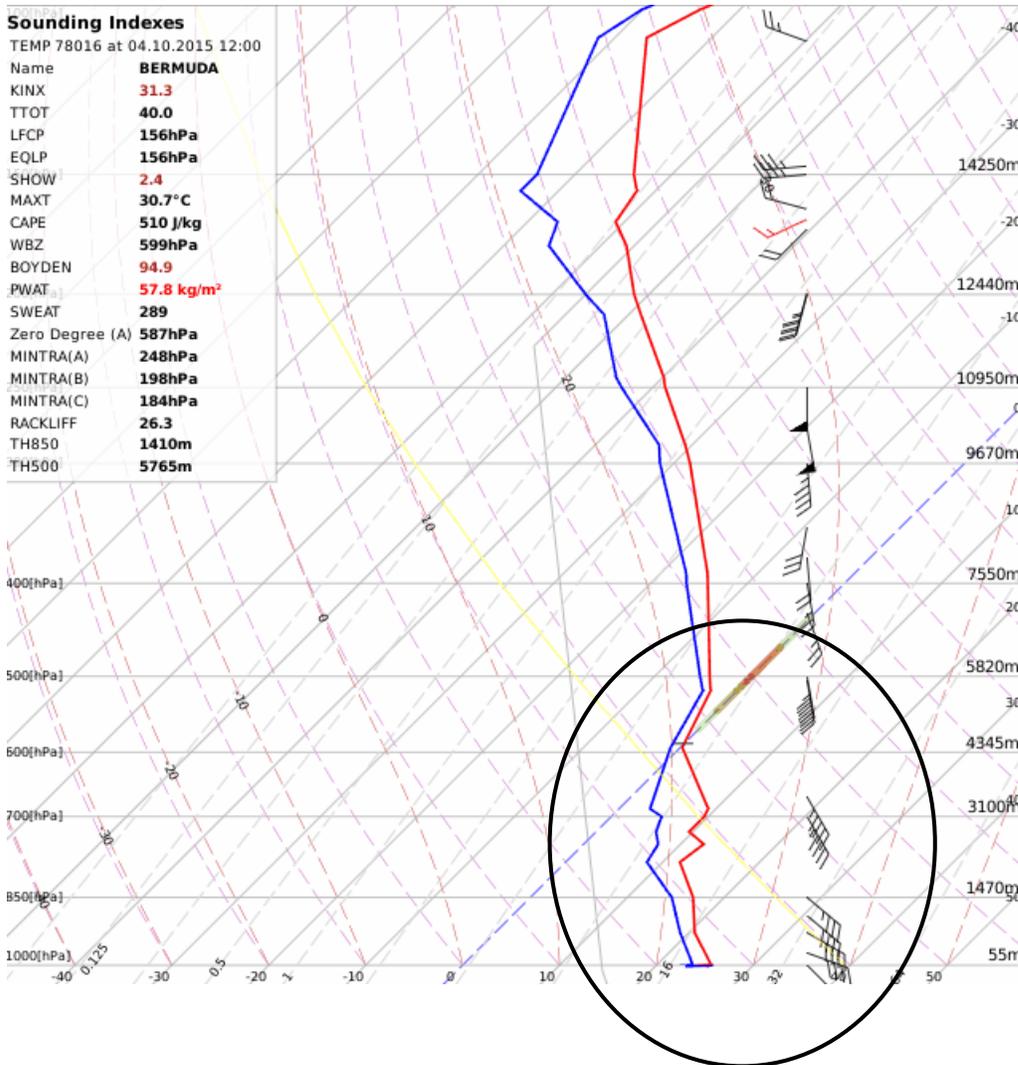
Specific Doppler Meso product, indicating two meso-vortices (circled in red) associated with the striations towards the north of the Island:



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Weather balloon/Radiosonde data -

The 12Z Bermuda sounding from the 4th October showed considerable instability in the lower 500mb of the atmosphere. This, coupled with significant wind shear through the same depth of atmosphere, provided strong indications of the possibility of tornadic activity associated with the hurricane. NOAA's Storm Prediction Center (SPC) communicated this risk to the NHC, who then incorporated a statement on Tornadoes into the 'Hazards Affecting Land' section of their 1500hrs advisory #28A on 4th October.

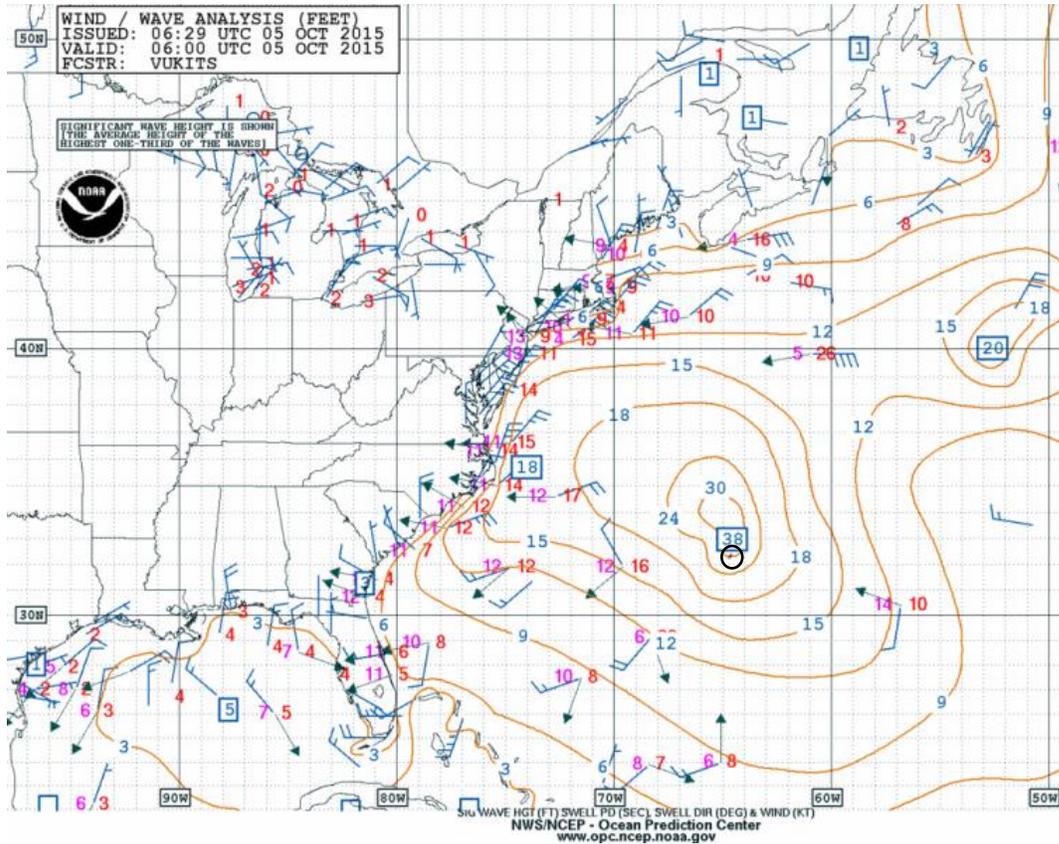


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QUALITY RECORD

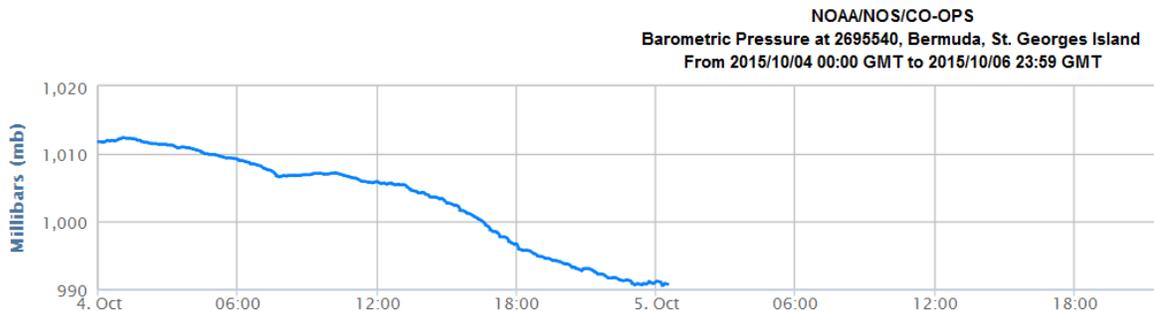
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Seas – The 06Z NOAA Ocean Prediction Center (OPC) analysis on Monday 5th October indicated seas in excess of 30ft around the Bermuda area (circled in black):



Pressure - NOAA Tide Gauge at Esso Pier, St George's

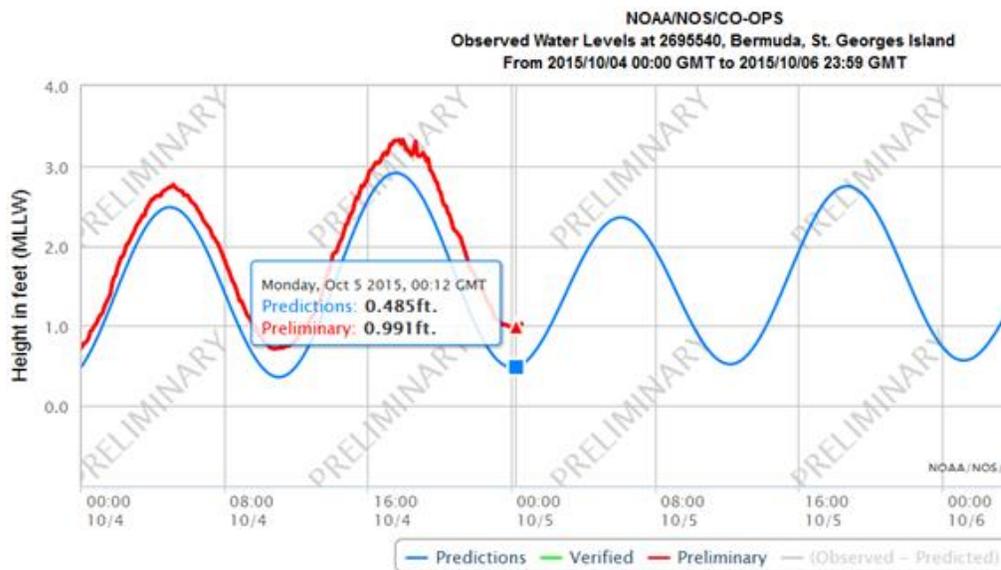
Barometer trace falling to 990.5mb/29.30inches at 0018Z on 5th October prior to outage:



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Tidal data from Esso Pier –

Observed data suggests a maximum storm surge/tide of around 0.5ft above the predicted tide level at 0012Z around the time of low tide, near 2100hrs local time Sunday evening:



Report published by:

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Bermuda Weather Service
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