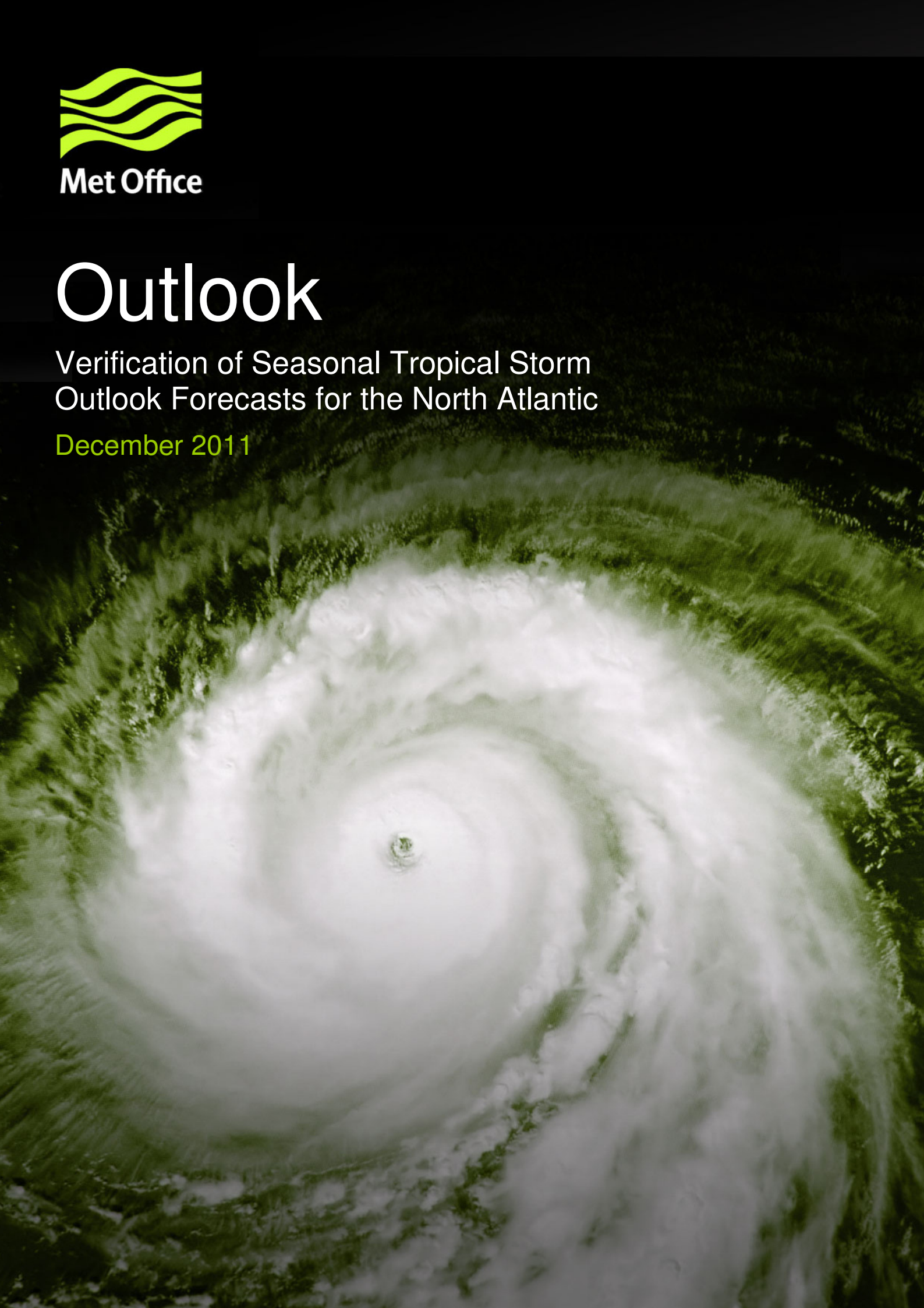
Met Office

Outlook

Verification of Seasonal Tropical Storm Outlook Forecasts for the North Atlantic

December 2011



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1. Executive Summary

The 2011 North Atlantic tropical storm season continued the recent trend of above average activity. Out of a total of 19 named storms, 7 became hurricanes (winds >73 mph) and of these 3 became major hurricanes (winds >110 mph). The combined accumulated cyclone energy (ACE) index — a measure of the combined strength and duration of tropical storms during the season — was 124. Despite the high numbers of storms, only one hurricane made landfall in the US (Irene), resulting in $4.3 billion in insured damages (iii, 2011).

Monthly updated forecasts issued by the Met Office over the period March to September 2011 provided good guidance on the ACE index with observed values always inside the predicted range. Predictions of tropical storm numbers provided good guidance from July onwards. For March to June issues, the observed values were outside of the predicted range on 3 out of 4 occasions.

Experimental multi-model forecasts of hurricane frequency matched observations well throughout 2011. Following further investigation of performance, forecasts of the number of hurricanes will be considered for release operationally.

2. The 2011 Hurricane Season

A summary of tropical storm activity in 2011 together with a corresponding plot of storm tracks is provided in the appendix. Based on historical records since 1944 the 2011 hurricane season was joint 2nd highest for named storms (19[1]), joint 19th highest for hurricanes (7[2]), joint 18th highest for major hurricanes (3) and 19th highest for ACE index (124). Only the 2005 hurricane season has recorded more named storms (28).

One hurricane (Irene) made landfall in the US causing an estimated $4.3 billion in insured damages (iii, 2011). This was the first US hurricane landfall since Ike in 2008. As in 2010 the majority of tropical storms either re-curved in the Atlantic — as a result of a north-eastward displacement of the Atlantic subtropical high, which steers storms northward, around the western portion of the subtropical high, and into higher latitudes — or occurred in the western Caribbean and southern Gulf. Only Don and Lee entered the northern Gulf and made US landfall as a tropical depression and tropical storm respectively. None of the first eight tropical storms of the 2011 season became hurricanes, which has never occurred before in the historical record.

The 2011 hurricane season was characterised by a large number of short-lived storms, which reached tropical storm strength for only 2 days or less. During the season, 7 out of 12 tropical storms were classified as short-lived (Arlene, Cindy, Franklin, Gert, Harvey, Jose and Unnamed storm), which resulted in a high tropical storm count, but a relatively low ACE index. Recent studies, such as Landsea *et al*. (2010), have examined the impact of tropical cyclone duration on annual storm counts. They found that the occurrence of short-lived storms in the Atlantic Hurricane Database (HURDAT, Jarvinen *et al*., 1984) has increased dramatically, from less than one per year in the late nineteenth–early twentieth century to about five per year since about 2000. In its end of season summary the National Oceanic and Atmospheric Administration (NOAA) suggested that many of the short-lived storms in 2011 may have gone undetected without modern satellite technology (NOAA, 2011).

Despite having a near record number of tropical storms in 2011, the ACE index and numbers of hurricanes were only moderately above the long term average. There are

[1] A previously unnamed system has been classified as a tropical storm following a post-season reanalysis http://www.noaanews.noaa.gov/stories2011/20111128_endofhurricaneseason_2011.html.
[2] Nate has been upgraded to a hurricane following a post-season reanalysis.

numerous examples in the historical database of ACE index being well above the value seen in 2011, but the total storm number being as low as 11 or 12 (e.g. 1951, 1955, 1961, 1964, 1966, 1980, 1989 and 1999). This anomaly is likely related to both the unusual nature of the 2011 season and the impact of modern satellite technology on storm detection.

3. Forecast Verification

3.1 Tropical Storm Frequency and ACE Index

A summary of forecast numbers of tropical storms and ACE index issued by the Met Office from March to September 2011, and the period they each covered, together with observed values is provided in Table 1. Each forecast was based on combined output from two world leading seasonal forecasting systems—the Met Office 'GloSea' system 4 and the ECMWF (European Centre for Medium Range Weather Forecasts) system 3—to create a 'multi-model' seasonal tropical storm forecast. The forecast periods vary due to the fixed 6 month forecast period provided by the dynamical systems from start date.

The 2011 season recorded 19 tropical storms (winds > 38 mph) and an ACE index of 124, above the long-term 1980–2010 average of 12 and 105, respectively. Forecasts of the number of tropical storms provided good guidance from July onwards. For March to June issues, the observed values were outside of the predicted range on 3 out of 4 occasions.

Predictions of ACE index provided good guidance of above-average activity, with observed values inside the predicted range for all forecasts issued.

The performance of the multi-model forecasting system for each start time, as measured by the long-term skill of retrospective forecasts (or hindcasts) covering the period 1996–2009, is provided in Table 2. Linear correlations between observed and predicted values of tropical storm numbers and ACE index are positive for all forecast lead times. Observations are obtained from the Atlantic hurricane database (HURDAT).

Forecast	Period of forecast	Tropical storms		ACE index	
		Forecast	Observed	Forecast	Observed
March	April–September	11 (6–15)	17	115 (41–189)	111
April	May–October	13 (8–18)	18	130 (65–195)	120
May	June–November	13 (10–17)	19	151 (89–212)	124
June	July–November	13 (8–17)	18	166 (87–245)	122
July	August–November	13 (9–17)	15	122 (67–177)	116
August	September–November	10 (6–15)	8	106 (57–155)	63
September	October–November	3 (1–5)	2	22 (6–39)	13

Table 1. Observed and forecast numbers of tropical storms and ACE index issued monthly from March to September 2011. Forecast best-estimates are calculated from the mean of the combined 83-member Met Office and ECMWF ensemble. Values in brackets represent ±1 standard deviation about the ensemble mean. Colours refer to forecast verification: green - observed values were within the predicted range, amber - observed values were outside the predicted range.

Forecast	Period of forecast	Forecast skill (linear correlation)	
		Tropical storms	ACE index
March	April–September	0.40	0.30
April	May–October	0.57	0.29
May	June–November	0.49	0.25
June	July–November	0.47	0.58
July	August–November	0.63	0.72
August	September–November	0.30	0.25
September	October–November	0.30	0.51

Table 2. Forecast skill (Pearson's linear correlation) of Met Office–ECMWF multi-model tropical storm and ACE index forecasts issued monthly from March to September. Skill is measured over the corresponding forecast period using hindcasts for 1996–2009. Perfect forecasts would have a skill of 1.0.

3.2 Experimental Hurricane Forecasts

Multi-model forecasts of the number of hurricanes have been run experimentally each month from March to August 2011. A summary of forecasts, together with observed values and an indication of hindcast skill (measured over the period 1996–2009), is provided in Table 3. Forecasts of hurricane activity for the September to November and October to November periods are not included as predictability for these periods has low skill. The 2011 season recorded 7 hurricanes, which represents near-normal activity relative to the 1980–2010 average of 6.5.

The observed numbers of hurricanes were inside the predicted range for all forecasts issued, although the predicted range is rather wide due to the spread of the ensemble. However, across all forecasts, the forecast best-estimate was not different from the

Forecast	Period of forecast	Hurricanes		
		Forecast	Observed	Skill
March	April–September	4 (0–9)	6	0.38
April	May–October	5 (0–11)	7	0.47
May	June–November	8 (3–13)	7	0.60
June	July–November	9 (3–15)	7	0.59
July	August–November	6 (2–11)	7	0.69
August	September–November	6 (2–10)	5	0.17

Table 3. Experimental forecast and observed numbers of hurricanes together with a summary of forecast skill (Pearson's linear correlation) measured using hindcasts for 1996–2009. Forecast best-estimates are calculated from the mean of the combined 83-member Met Office and ECMWF ensemble. Values in brackets represent ±1 standard deviation about the ensemble mean. Green boxes show instances when observed values were within the predicted range.

observed values by more than two. Linear correlations over the hindcasts between observed and predicted numbers of hurricanes are positive for all forecast lead times shown. The use of multi-model hurricane forecasts for the 2012 season is now being considered.

3.3 Evaluation of 2011 Predictions

This year three of the predictions of storm numbers fell outside of the predicted range. It should first be highlighted that the observed number of tropical storms in a given year is, by definition, expected to lie within the 70% prediction interval approximately 7 out of 10 times. Thus in some years the observed number will lie outside of this range and this is consistent with the stated uncertainty in the forecast. However, it is of interest to consider reasons for the overall low bias in predicted storms this season.

Firstly, warmer than observed sea-surface temperatures (SSTs) in the tropical Pacific Niño3.4 region were predicted by the multi-model consensus. This may have had the effect of depressing the predicted storm numbers since it promotes vertical wind shear in areas of the tropical Atlantic where the majority of tropical storms form.

Secondly, since seasonal tropical storm forecasts are calibrated based on historical numbers, the increase in short-lived storms over the recent period may result in an under-estimate of the predicted number of storms during the season. In addition, the method used to count model tropical storms excludes any systems with a duration of less than two days to prevent picking up transient disturbances and depressions. However, this may on occasions have the effect of excluding some weak and short-lived storms. Planned increases in the horizontal resolution of seasonal models may allow for a better distinction between weak tropical storms and tropical depressions, which may also help in the prediction of unusual seasons like 2011 in the future.

Despite some predictions of storm numbers lying outside the forecast range, all predictions of ACE index were within the predicted range.

The number of medium- to long-duration tropical cyclones have increased little, if at all, as a result of changes in observing practices (Landsea *et al*. 2010). The Met Office has been researching the skill of predicting the number of hurricanes, the majority of which have medium to long duration. Results of experimental forecasts during the 2011 season have shown that there is skill in predicting hurricane frequency in the Atlantic using dynamical forecasting systems. As a result, following a final assessment of performance, these forecasts will be considered for release operationally.

4. Concluding Remarks

- Multi-model seasonal forecasts issued by the Met Office between March and September 2011 provided good guidance on the ACE index throughout the season.
- Forecasts of the number of tropical storms provided good guidance from July onwards. Between March and June, forecasts under-predicted the observed number of tropical storms on three out of four occasions. This is possibly due to a prediction of warmer than observed sea-surface temperatures in the tropical Pacific Niño3.4 region in the multi-model consensus, which may have depressed predicted storm numbers. Another contributing factor is that the number of short-lived storms (duration of 2 days or less) has increased in recent years due to improvements in observing practices. This season, 7 out of 12 tropical storms were classed as short-

lived. Since the seasonal forecasts are calibrated based on historical numbers, it is possible that we are not accounting for an increase in the frequency of these storms in the forecast calibration process. Furthermore, short-lived systems are not counted in model predictions to prevent the counting of transient disturbances. These factors may have contributed to under-prediction of storm numbers this year.

- Experimental forecasts of hurricane activity performed well throughout 2011. Following further investigation of performance, forecasts of the number of hurricanes will be considered for release operationally.

- The 2011 hurricane season recorded one US landfalling hurricane (Irene). This season (together with 2010) provide examples of when the total numbers of tropical storms and ACE index are not good indicators of landfall or damages in the US. Further work is needed to assess the mechanisms that control landfall in the US and their predictability on seasonal timescales.

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Appendix

Storm name	Active dates	Category	Maximum wind speed (mph)	Minimum central pressure (hPa)	ACE index (10^4 kt^2)
Arlene	29 June–1 July	TS	65	993	1.71
Bret	17–22 July	TS	65	996	2.99
Cindy	20–23 July	TS	70	994	1.72
Don	27–30 July	TS	50	998	1.30
Emily	1–7 August	TS	50	1003	2.07
Franklin	12–14 August	TS	45	1004	0.69
Gert	14–16 August	TS	60	1000	1.73
Harvey	18–22 August	TS	60	994	1.36
Irene	20–29 August	H3	120	942	20.47
Jose	28–29 August	TS	45	1007	0.69
Katia	29 August–10 September	H4	135	946	25.93
Lee	1–5 September	TS	60	986	1.91
Maria	6–16 September	H1	80	979	8.95
Nate	7–12 September	H1	75	994	4.43
Ophelia	21 September–3 October	H4	140	940	19.57
Philippe	24 September–9 October	H1	90	976	15.35
Rina	23–28 October	H2	110	966	9.21
Sean	8–12 November	TS	65	983	3.77

Saffir–Simpson hurricane wind scale

Tropical depression (0–39 mph) Tropical storm (39–73 mph) Category 1 (74–95 mph) Category 2 (96–110 mph)
Category 3 (111–130 mph) Category 4 (131–155 mph) Category 5 (> 155 mph)

Table 4. Summary of tropical cyclone activity during the 2011 hurricane season. Please note that final details may change during post-analysis of the season and details of tropical depressions (wind speeds of approximately 30 mph) and the unnamed tropical storm have been excluded. Colours refer to maximum storm intensity (based on the Saffir-Simpson hurricane wind scale). ACE index values from http://policlimate.com/tropical/index.html.

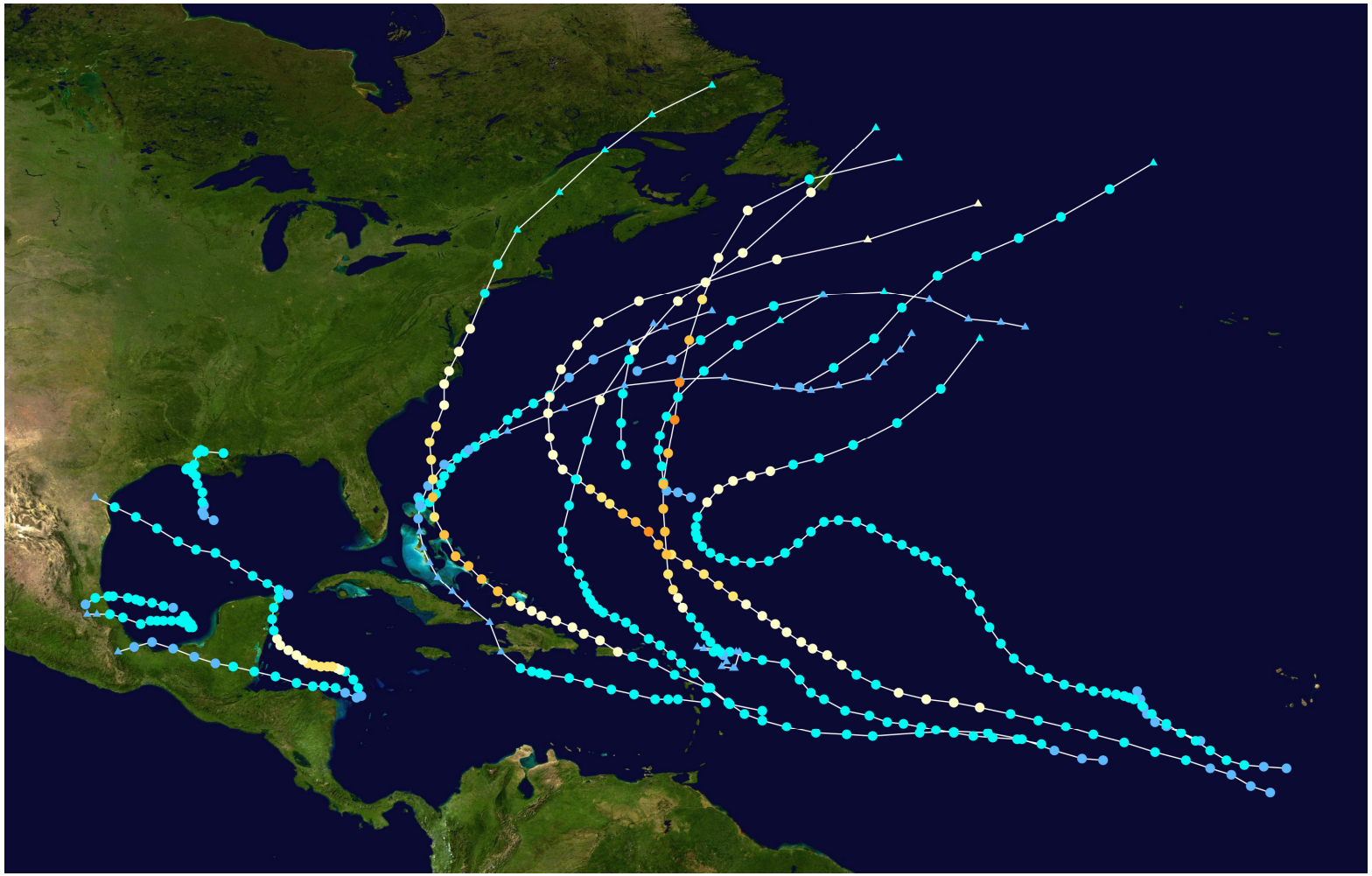

Figure 1. Preliminary tracks of all tropical depressions (wind speeds of approximately 30 mph) and named storms which occurred during the 2011 hurricane season (updated 8th November 2011). Colours refer to storm intensity (based on the Saffir–Simpson hurricane wind scale) at each 6 hour interval. Source: http://en.wikipedia.org/wiki/2011_Atlantic_hurricane_season.

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