Met Office

Outlook

Verification of 2012 Seasonal Tropical Storm Forecasts for the North Atlantic

November 2012

Contents

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1. Executive Summary

The 2012 North Atlantic tropical storm season continued the recent trend of above average activity. Out of a total of 19 named storms, 10 became hurricanes (winds >73 mph) and of these one became a major hurricane (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 127. Despite the high number of storms, only two hurricanes made landfall in the US (Isaac and Sandy[1]), resulting in a combined estimate of $52 billion in insured damages.

Monthly updated forecasts issued by the Met Office over the period March to September 2012 provided good guidance on the ACE index with observed values inside the predicted range for all forecasts issued, apart from July. Predictions of tropical storm numbers were within the predicted range from forecasts issued in March, August and September. For forecasts issued in April to July, the observed values were outside of the predicted range. Experimental forecasts of hurricane frequency using the Met Office seasonal forecasting system were run each month from March to August 2012. Forecasts starting in March, May and August verified well; the remaining forecasts (April, June and July) under-predicted the number of hurricanes.

The underestimate in tropical storm and hurricane activity during 2012 is likely due to an over-prediction of the degree of warming of sea-surface-temperatures (SSTs) in the tropical Pacific Niño3.4 region (El Niño conditions) during the hurricane season. In the event, SSTs only rose to weak El Niño thresholds and the typical atmospheric responses to El Niño did not develop, resulting in the atmosphere remaining in a neutral state (i.e. neither El Niño nor La Niña) overall (WMO, September 2012). Thus, the suppression of tropical storm activity that would typically occur in the Atlantic during an El Niño event was not present, although hurricane development in the deep tropics was somewhat suppressed and major hurricane development was below average.

2. The 2012 Hurricane Season

A summary of tropical storm activity in 2012 together with a corresponding plot of storm tracks is provided in the appendix. Based on historical records since 1944 the 2012 hurricane season was joint 2nd highest for named storms (19), joint 6th highest for hurricanes (10), 19th highest for ACE index (127), but joint 5th lowest for major hurricanes (1). 2012 marks the third season in a row to record 19 tropical storms. Only the 2005 hurricane season has recorded more named storms (28) during this historical period.

Two hurricanes (Isaac and Sandy[1]) made landfall in the US causing an estimated $2.0 billion (Reuters 2012a) and $50 billion (Reuters 2012b) in insured damages, respectively. Similarly to 2010 and 2011, the majority of tropical storms during the season were steered away from the US, due to the presence of a mid-level trough and strong south-westerly flow over the western North Atlantic. Only Isaac and Debby entered or formed in the northern Gulf of Mexico and made US landfall as a category 1 hurricane and tropical storm respectively.

Four tropical storms (Ernesto, Isaac, Rafael and Sandy) entered of formed in the Caribbean Sea. Isaac made landfall in Haiti and eastern Cuba and Rafael passed close to Puerto Rico and the British Virgin Islands. Sandy and Ernesto intensified into hurricanes: Sandy made

[1] It is possible that Sandy will not count as a US hurricane landfall as it completed transition to a post-tropical cyclone prior to landfall. This will be confirmed in a post-season reanalysis due to be completed by the National Hurricane Center in early 2013.

landfall over Jamaica and Cuba before heading toward the northeast coast of the US and Ernesto made landfall over Central America.

In addition to the trough over the eastern US, the Atlantic subtropical high was weaker than in 2010 and 2011. This resulted in lower than normal pressures over the subtropical Atlantic and caused some of the developing storms in the far eastern Atlantic to re-curve and intensify into hurricanes north of the Main Development Region (MDR) — a region comprising the tropical Atlantic Ocean and Caribbean Sea from 9.5°N–21.5°N, 20°W–87°W where the majority of hurricanes in an active season form (Goldenberg et al 2001).

The pressure pattern in the subtropical North Atlantic also enabled tropical storms that formed in the western MDR to move westward and enter the Caribbean Sea and northern Gulf of Mexico instead of re-curving into higher latitudes and back out to sea. Two of these tropical storms (Ernesto and Isaac) later strengthened into hurricanes before making landfall along the Yucatan Peninsula and the US coast of Louisiana, respectively.

Anomalously high pressure was present over Atlantic Canada and Greenland. This region of high pressure influenced the path of Hurricane Sandy, causing it to make an unusual turn to the northwest before making landfall along the northeast coast of the US.

The 2012 season was characterised by a high level of early season activity, with tropical storms Alberto and Beryl forming before the official start of the season (1 June). By 1 July, four named storms had formed in the Atlantic (Alberto, Beryl, Chris and Debby) for the first time since records began in 1851. Although no storms formed in July, eight tropical storms formed in August, tying the record for the most named storms for the month set in 2004. In October, Hurricane Nadine became tied in the records with Tropical Storm Ginger (1971) as the second-longest-lasting Atlantic tropical storm since 1851, lasting 21.25 days. Nadine also made the top five longest-lasting Atlantic tropical cyclones since 1851, which includes the tropical depression stage (wind speeds of approximately 30 mph), at 21.75 days.

A feature of recent tropical storm seasons has been the contribution of short-lived storms, which reach tropical storm strength for only 2 days or less, to the total tropical storm count. During the 2012 season, 7 out of 9 tropical storms were classified as short-lived (Alberto, Florence, Helene, Joyce, Oscar, Patty and Tony). These storms contributed towards a high tropical storm count, but very little towards the ACE index. Recent studies, such as Landsea *et al*. (2010), have examined the connection between tropical cyclone duration and 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. The reason for the increase in short-lived storms is likely due to modern satellite technology and, in particular, continuous coverage of tropical storm activity in the eastern tropical Atlantic, without which many of the short-lived storms, particularly those in 2011 (NOAA 2011), may have gone undetected.

Despite having a near-record number of tropical storms in 2012, the number of major hurricanes (1) was below the 1944–2011 average of 2.7 and the ACE index was only moderately above the 1944–2011 average of 101. There are numerous examples in the historical database of ACE index being well above the value seen in 2012, 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 2012 season (discussed in section 3.3 below) 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 2012, together with the period they each covered and corresponding observations, 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 4—to create a 'multi-model' seasonal tropical storm forecast.

The 2012 season recorded 19 tropical storms (winds > 38 mph) and an ACE index of 127. Both the numbers of tropical storms and ACE index were above the long-term 1980–2010 averages of 12 and 105, respectively. Predictions of the number of tropical storms provided good guidance from forecasts issued in March, August and September. The forecasts issued in April to July underestimated the number of tropical storms and the observed values fell outside of the predicted range.

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

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, with the greatest skill for both numbers of tropical storms and ACE index forecasts starting in August (linear correlations of 0.6).

Forecast	Period of forecast	Tropical storms		ACE index	
		Forecast	Observed	Forecast	Observed
March	April–September	10 (6–14)	14	85 (22–148)	102
April	May–October	11 (7–15)	19	96 (27–165)	127
May	June–November	10 (7–13)	17	90 (28–152)	123
June	July–November	10 (7–13)	15	85 (32–138)	118
July	August–November	8 (5–11)	15	66 (21–111)	118
August	September–November	7 (4–10)	7	59 (27–91)	67
September	October–November	3 (1–5)	5	22 (10–34)	25

Table 1. Observed and forecast numbers of tropical storms and ACE index issued monthly from March to September 2012. Forecast best-estimates are calculated from the mean of the combined 93-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	0.18	0.16
April	May–October	0.32	0.07
May	June–November	0.39	0.36
June	July–November	0.36	0.52
July	August–November	0.46	0.58
August	September–November	0.60	0.60
September	October–November	0.31	0.46

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. Historical observations are obtained from the Atlantic hurricane database (HURDAT).

3.2 Experimental Hurricane Forecasts

Forecasts of the number of hurricanes have been run experimentally using the Met Office seasonal forecasting system (GloSea) each month from March to August 2012. 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 October to November period (starting in September) are not included as the predictive skill for this period is low. The 2012 season recorded 10 hurricanes, which represents above-normal activity relative to the 1980–2010 average of 6.5.

Forecast	Period of forecast	Hurricanes		
		Forecast	Observed	Skill
March	April–September	6 (3–9)	8	0.14
April	May–October	6 (4–8)	10	0.16
May	June–November	6 (2–10)	10	0.36
June	July–November	5 (2–8)	9	0.43
July	August–November	3 (1–5)	9	0.36
August	September–November	4 (2–6)	4	0.60

Table 3. Experimental forecast and observed numbers of hurricanes together with a summary of forecast skill (Pearson's linear correlation) measured using hindcasts over the period 1996–2009. Historical observations of hurricane numbers are obtained from the Atlantic hurricane database (HURDAT). Forecast best-estimates are calculated from the mean of the 41-member Met Office 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.

Predictions of the number of hurricanes verified well from forecasts produced in March, May and August; however observed values were typically at the upper end of the predicted range. The remaining forecasts (produced in April, June and July) under-predicted the number of hurricanes and the observed value fell outside the predicted range.

Linear correlations between observed and predicted numbers of hurricanes as measured using hindcasts are positive for all forecast lead times shown (table 3), showing that the GloSea forecasting system has skill over climatology to predict numbers of hurricanes during the period 1996–2009.

3.3 Evaluation of 2012 Predictions

This year the observed number of tropical storms fell outside the forecast range on 4 out of 7 occasions. Each time, the observed number of tropical storms was higher than predicted by the multi-model. 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, the greatest influence on the tropical storm forecasts would have been from the predicted positive phase of ENSO (El Niño-Southern Oscillation) throughout the season. This would have had the effect of depressing the predicted storm numbers, since it promotes high vertical wind shear in areas of the tropical Atlantic where the majority of tropical storms form. However, in the event, SSTs in the Niño3.4 region remained cooler than predicted and only rose to a level indicative of a weak El Niño (WMO 2012). In addition, features characteristic of El Niño (e.g. in patterns of sea level pressure, winds and cloudiness) did not develop and thus the climate system remained in a neutral state overall (WMO 2012). Therefore, the typical atmospheric teleconnection response to El Niño in the tropical North Atlantic (high vertical wind shear), and the corresponding suppression of tropical storm activity, did not occur.

It is worth noting however that despite the high number of tropical storms, only one major hurricane (Michael) formed during the 2012 season and this formed outside the tropics. Furthermore, out of the 10 hurricanes that formed during the season, only two of these (Ernesto and Sandy) became hurricanes within the MDR. Thus, although the ENSO teleconnection in the atmosphere was not strong enough to inhibit tropical storm genesis throughout the tropics, it likely influenced the maximum intensity that the storms were able to attain and so limited their contribution to the season's ACE index total. Thus, despite the high numbers of tropical storms the ACE index was only slightly above-normal and this was well predicted by the multi-model system, with all forecasts, apart from the July issue, verifying well.

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. In 2012 seven of the storms were below this threshold duration. Planned increases to the horizontal resolution of the Met Office seasonal forecasting system in December 2012 may allow for a better distinction between weak tropical storms and tropical depressions, which may help seasonal predictions of tropical storm numbers in the future.

It is worth noting that 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 2012 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. Although the real-time forecasts issued during 2012 under-estimated the level of hurricane activity, the positive hindcast skill over the period 1996-2009 shows that there is skill in predicting hurricane frequency in the Atlantic using dynamical forecasting systems.

4. Concluding Remarks

- Multi-model seasonal forecasts issued by the Met Office between March and September 2012 provided good guidance on the ACE index throughout the season, with observed values falling within the predicted range for all forecasts apart from that issued in July.
- Forecasts of the number of tropical storms provided good guidance from March, August and September. Between April and July, the forecasts under-predicted the observed number of tropical storms.
- Experimental forecasts of hurricane activity using the Met Office seasonal forecasting system performed well from March, May and August; the remaining forecasts under-estimated the number of hurricanes.
- The under-estimate in tropical storm and hurricane activity during the 2012 season is likely 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.
- The 2012 hurricane season recorded two US landfalling hurricanes (Isaac and Sandy [1]). This season, like 2010 and 2011, is an example of when the total number of tropical storms is not a good indicator of the frequency of landfall 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)
Alberto	19–22 May	TS	60	995	1.06
Beryl	26–30 May	TS	70	992	2.51
Chris	19–22 June	H1	75	987	3.02
Debby	23–27 June	TS	60	990	2.73
Ernesto	1–10 August	H1	85	980	7.77
Florence	3–6 August	TS	60	1002	1.44
Gordon	15–20 August	H2	110	965	8.06
Helene	9–19 August	TS	45	1004	0.37
Isaac	21 August–1 September	H1	80	968	9.56
Joyce	22–24 August	TS	40	1006	0.25
Kirk	28 August–2 September	H2	105	970	7.40
Leslie	30 August–11 September	H1	75	968	15.38
Michael	3–11 September	H3	115	964	16.86
Nadine	11 September–4 October	H1	90	978	25.47
Oscar	3–5 October	TS	50	997	1.09
Patty	11–13 October	TS	45	1005	0.65
Rafael	12–17 October	H1	90	969	7.50
Sandy	22–31 October	H2	110	940	14.26
Tony	22–25 October	TS	50	1000	1.62

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 (111–129 mph) Category 4 (130–156 mph) Category 5 (> 156 mph)

Table 4. Summary of tropical cyclone activity during the 2012 hurricane season. Please note that final details may change during post-analysis of the season. There were no tropical depressions (wind speeds of less than 39 mph) which did not attain at least tropical storm status in 2012. Colours refer to maximum storm intensity (based on the Saffir-Simpson hurricane wind scale). ACE index values from http://policlimate.com/tropical/index.html.

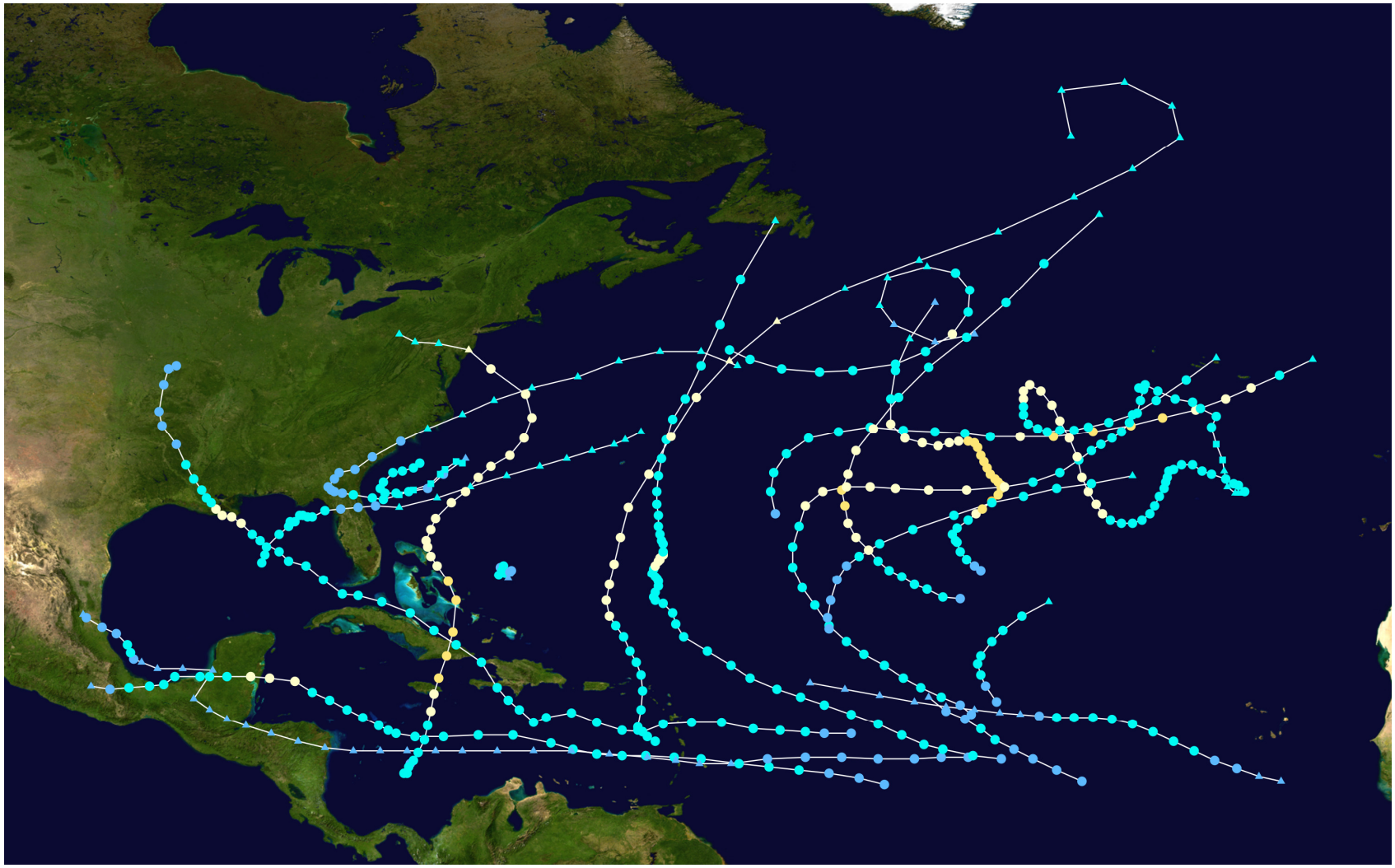

Figure 1. Preliminary tracks of all named tropical storms which occurred during the 2012 hurricane season (updated 12th November 2012). Colours refer to storm intensity (based on the Saffir–Simpson hurricane wind scale) at each 6 hour interval. Source: http://en.wikipedia.org/wiki/2012_Atlantic_hurricane_season.

Met Office
FitzRoy Road, Exeter
Devon, EX1 3PB
United Kingdom

Tel: 0870 900 0100
Fax: 0870 900 5050
enquiries@metoffice.gov.uk
www.metoffice.gov.uk

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