Met Office
Hadley Centre

# Appraisal of the 2009 Met Office seasonal tropical storm forecast for the North Atlantic

## Contents



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## Executive Summary

The Met Office seasonal tropical storm forecast for the North Atlantic, issued on the 18th June 2009, predicted below-normal activity for the July to November 2009 period, with a best estimate of 6 tropical storms (with a range 3–9) and an Accumulated Cyclone Energy (ACE) index of 60 (range 40–80). The best estimate therefore predicted the quietest July to November period for more than a decade; the last season with 6 or fewer tropical storms was in 1992 (6) and the last season with an ACE index of 60 or less was in 1997 (38.8).

In the event the observed number of storms (9) and the observed ACE index (52.4) were both within the predicted ranges, and well below the 1990–2005 July–November averages of 12.4 and 131 respectively. Thus in terms of ACE index the season was indeed the quietest for over a decade. In terms of tropical storm numbers only 2006 has recorded 9 or fewer tropical storms in the last decade (9 storms were recorded in the July to November period 2006).

There is good evidence that relatively strong vertical wind shear, particularly in the western Main Development Region and over the Caribbean, was a key factor in the observed below-normal activity. Strong vertical wind shear in the tropical North Atlantic is known to be associated with El Niño events and a weak-to-moderate El Niño became established in July and has been maintained through the season. The developing El Niño was well predicted by the Met Office seasonal forecast system, and this is likely to have been crucial in the successful prediction of below-normal activity.

## 1. Introduction

Seasonal forecasts of tropical storm activity for the North Atlantic basin have been provided to the public by the Met Office since 2007. The forecasts are produced using the Met Office global seasonal forecasting system known as

GloSea. GloSea is a dynamical prediction system which uses a model with full interactive coupling between ocean and atmosphere. The number of tropical storms developing in the seasonal predictions can be counted (the tracking algorithm of Vitart and Stockdale (2001) is currently used), and this forms the basis of the forecast. Importantly, GloSea is skilful in predicting the evolution of large-scale ocean-atmosphere processes, such as ENSO (El Niño Southern Oscillation), which influence the degree of tropical storm activity in the North Atlantic, and this gives rise to skilful forecasts of tropical storm numbers and Accumulated Cyclone Energy (ACE) index. (The ACE index is a measure of the collective intensity and duration of tropical storms during the season (Bell *et al.*, 2000).)

GloSea is an ensemble prediction system which provides a range of possible outcomes, thus allowing a detailed breakdown of the probability of various ranges of tropical storm activity, an advantage that is not readily available from statistical methods. To generate the ensemble, the starting conditions for the forecast are varied slightly to make 41 individual predictions (known as ensemble members). The forecast probability that the number of storms will lie in pre-defined ranges, or categories (e.g. 10 to 12 storms) and that a certain threshold of activity will be exceeded (e.g. more than 12 storms) are derived by counting the proportion of ensemble members that predict storm numbers in that category or above the specified exceedence threshold.

The average number of storms over all ensemble members (the ensemble mean) is derived to provide the single ‘best-estimate’ forecast, and the two-standard-deviations measure of the ensemble dispersion is used to provide the predicted range on the best estimate. It should be noted that the best estimate and predicted range are simplifications of the more detailed information provided in the predicted probability distributions.

The use of dynamical prediction systems to forecast tropical storm activity represents a relatively new methodology in operational tropical storm forecasting. Traditionally such forecasts have been made using statistical prediction methods. Statistical methods do not model atmospheric processes, but rely on past relationships between tropical storm numbers and preceding observed conditions (e.g. sea surface temperatures patterns). Research by Vitart (2006) and Vitart *et al*. (2007) indicates that the skill of dynamical systems for Atlantic basin tropical storm frequency is now comparable with, or greater than, that of some well-known statistical methods. Notably, GloSea and some other dynamical systems successfully distinguished between the very active season of 2005 and the following below-normal season of 2006 — a year-to-year change that was not captured by published statistical methods.

## 2. Met Office seasonal forecast of North Atlantic tropical storm activity for 2009

Two types of prediction were made. A deterministic best-estimate forecast (released to the public on 18th June 2009) and a more detailed forecast providing the probability of different activity ranges and thresholds.

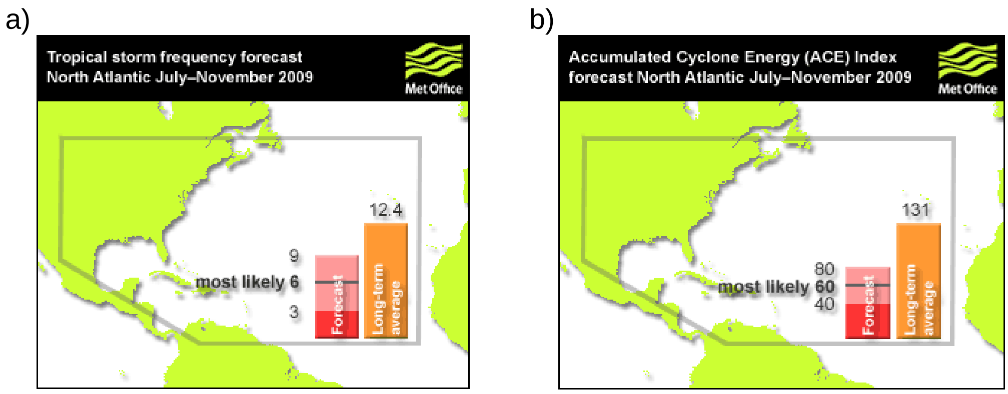


***Figure 1.*** *Met Office seasonal forecasts for a) tropical storm numbers and b) ACE index for the North Atlantic basin over the period July to November 2009.*

The best-estimate predictions were for 6 tropical storms, with a two-standard-deviation range of 3 to 9 (Fig. 1a), and an ACE index of 60, with a two-standard-deviation range of 40 to 80 (Fig. 1b). This represented below-normal activity relative to the 1990–2005 long-term average number of storms and ACE index of 12.4 and 131 respectively. The best estimate forecasts predicted the quietest July–November period for over a decade; the last season with 6 or fewer tropical storms was in 1992 (6) and the last season with an ACE index of 60 or less was in 1997 (38.8).

Probability forecasts for the number of tropical storms and ACE index are shown in Fig. 2, and quantify the predicted probability of below-normal activity. The forecast indicated a very high probability (~100%) of 15 or fewer storms (15 were observed in the period July–November 2008), and a high probability (58.5%) of fewer than 7 tropical storms – compared to a climatological chance of 13.6%. The forecast also indicated a high probability, 85.4%, of 9 or fewer storms relative to a climatological probability of 31.8% (see the forecast report) – 9 storms being the upper end of the predicted range on the best estimate. At the time the forecast was issued only the 2006 season had recorded 9 or fewer tropical storms (from July to November) in the last decade.

The predicted probabilities for the ACE index (Fig. 2b) indicated a very high probability (97.6%, not directly shown) of a lower index than observed in 2008 (143.7), with a strongly enhanced probability (65.9%) of a particularly inactive season with an ACE index less than 70. The previous year with an ACE index less than 70 over the July to November period was 2002. The forecast also gave a high probability (65.9%) of an ACE index of 60 (the forecast best-estimate) or less, relative to a climatological probability of 22.7% (see forecast report). As noted above, the last season with an ACE index of 60 or less was 1997, when 38.8 was recorded.

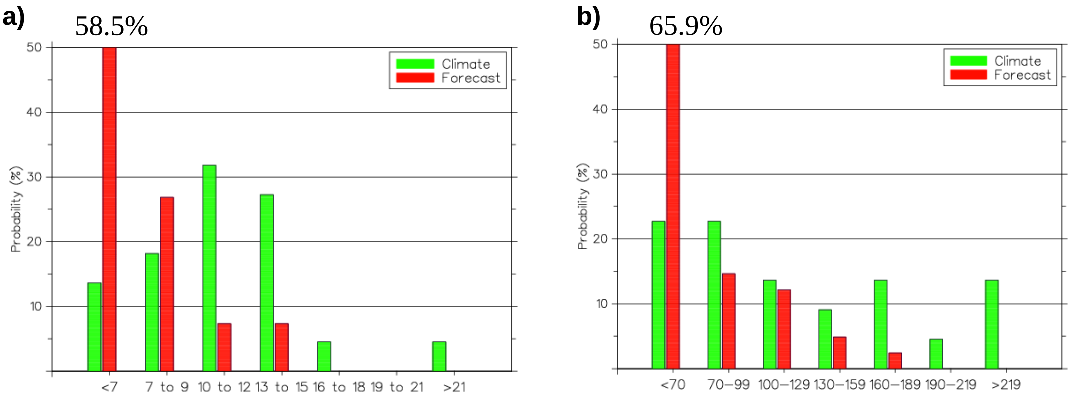


***Figure 2.*** *Probability that a) the number of Atlantic basin tropical storms and b) the ACE index will lie within given ranges. Red bars indicate the forecast probabilities for July–November 2009 based on the GloSea prediction system. Green bars indicate the climatological frequency (1987–2008) derived from NOAA's HURDAT dataset.*

## 3. Appraisal of the Met Office (June-issued) seasonal forecast for 2009

### 3.1 Observed tropical storm activity

During July–November 2009, 9 tropical storms formed (of which 3 became hurricanes) with a total ACE index of 52.4. Thus in terms of ACE index the season was indeed the least active for over a decade, and the second least active since the ongoing active hurricane era began in 1995 (Goldenberg *et al.*, 2001). With regard to tropical storm numbers, 2009 was the second least active year since 1995, only 1997 having had fewer storms (7), while 2006 had the same number of storms (9).

Our forecast did not include predictions of the number of storms reaching hurricane strength, but we note that the level of hurricane activity was also the lowest for over a decade. The last time no more than 3 hurricanes formed was in 1997 and only 10 seasons (July to November) have recorded 3 or fewer hurricanes since 1950.

An important feature of the 2009 season was the low ACE index (52.4). This is the lowest ACE index since 1997 (38.8) and the 12th lowest since 1972, when Dvorak estimates of tropical storm intensity became available from satellites.

## 3.2 Appraisal of predicted tropical storm numbers and ACE index

An appraisal of the Met Office deterministic forecasts of the number of tropical storms and ACE index for the July–November period is provided in Table 1. The observed number of tropical storms (9) and ACE index (52.4) from July to November 2009 were both within the range predicted. The observed number of tropical storms was at the upper end of the predicted range (3–9) while the ACE index was within the central 50% (50–70) of the range.

| | Predicted for July to November | | Observed |
|---|---|---|---|
| | Best estimate (range) | Climate | |
| No. tropical storms | 6 (3–9) | 12.4 | 9 |
| ACE index | 60 (40–80) | 131.0 | 52.4 |

***Table 1.*** *Appraisal of the Met Office deterministic seasonal forecast for the period July–November 2009. The climate averages for numbers of tropical storms and ACE index are based on observations for the period 1990–2005.*

An appraisal of the probability forecasts available as part of the forecast report is shown in Table 2. The observed tropical storm category (7–9) was one category above the category predicted most likely (<7) and one category below the climate

| | Predicted for July to November | | Observed |
|---|---|---|---|
| | Forecast mode | Climate mode | |
| No. tropical storms | <7 | 10–12 | 7–9 |
| ACE index | <70 | <70, 70–99 | <70 |

***Table 2.*** *Appraisal of the probability forecasts. The forecasts provided probabilities (for the period July–November) that the observed number of tropical storms would be in the ranges <7, 7–9, 10–12, 13–15, 16–18, 19–21 and >21 and probabilities that the observed ACE index would fall in the ranges <70, 70–99, 100–129, 130–159, 160–189, 190–219 and >219 (see Fig. 2). Reference climatology used for the probability forecast was 1987–2008. The climate mode is the category observed most frequently over the 1987–2008 period. The forecast mode is the category with the highest predicted probability.*

mode (10–12). The observed category for ACE index (<70) was the category predicted most likely.

### 3.3 Tropical Pacific and North Atlantic SST

North Atlantic tropical storm activity is known to be positively correlated with anomalies in North Atlantic sea surface temperatures (SST), and negatively correlated with tropical Pacific SST (Gray, 1984). In June 2009, GloSea-predicted SST anomalies for August-September-October (Fig. 3) indicated below-normal SST (up to -0.75°C) in the North Atlantic Main Development Region (MDR, 10°N–20°N, 20°W–60°W) and above-normal SST in the tropical Pacific Niño3.4 region (5°S–5°N, 120°W–170°W). Predicted positive anomalies in the Niño.3.4 region indicated the development of El Niño type conditions, and this was supported by international consensus, co-ordinated by the World Meteorological Organisation (WMO). El Niño conditions and below-normal SST in the tropical North Atlantic favour suppressed North Atlantic tropical storm activity.

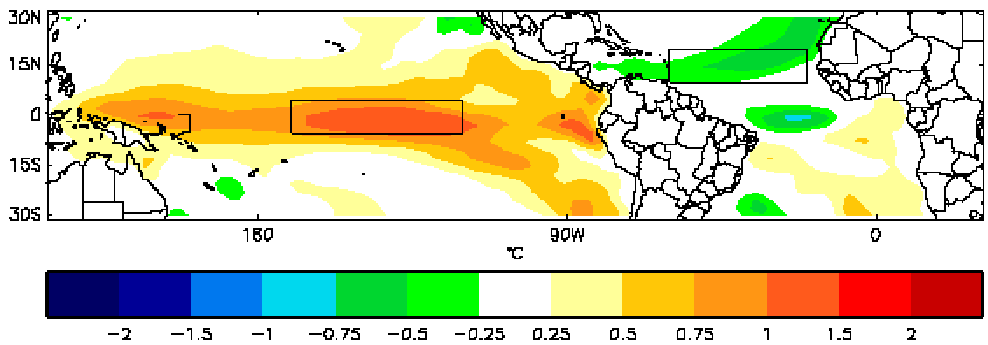


***Figure 3****: Ensemble-mean sea-surface temperature anomalies for August-September-October predicted from June 2009. Anomalies are expressed relative to the 1987–2001 period. The boxed areas shown are the Niño3.4 region in the tropical Pacific and the Main Development Region in the tropical North Atlantic.*

Observed global and North Atlantic SST anomalies for the period August-September-October 2009 are provided in Fig. 4. In the MDR, SSTs were within ±0.5°C of 1985–2001 normals for this period, except in the extreme east of the region where anomalies were greater than +0.5°C. Positive anomalies (of order +1.0°C) were also observed in the Gulf of Mexico and the northern Caribbean Sea. The forecasts of SST in these regions (Fig. 3) therefore exhibited a slight cold bias. Negative SST anomalies were present over much of the tropical North Atlantic at the beginning of the hurricane season, and the GloSea system appears to have maintained these anomalies too long into the forecast.

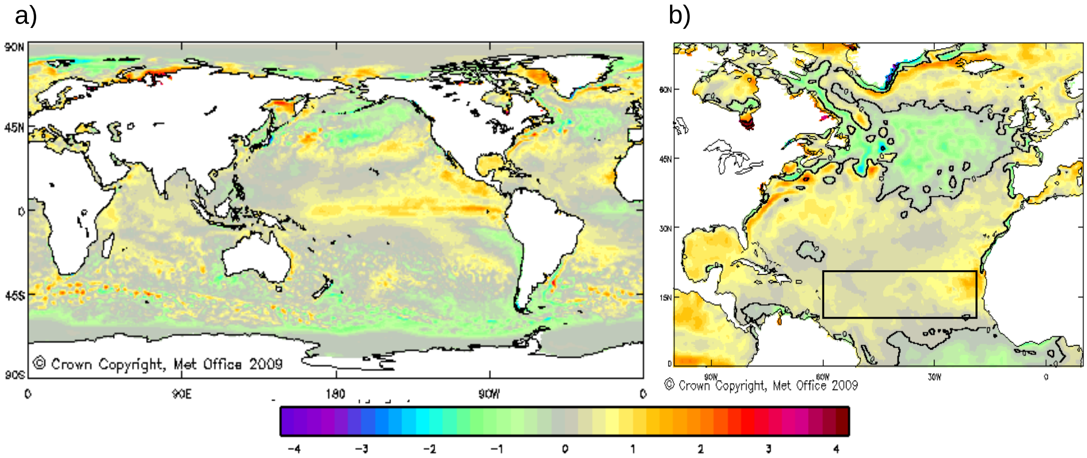


***Figure 4.*** *Observed a) global and b) North Atlantic SST anomalies for 1st August– 1st November 2009. Anomalies are derived from the Met Office Operational SST and Sea Ice Analyses (OSTIA) and NCEP OIv2 climatology 1985–2001.*

Observed August-September-October SST anomalies were positive over much of the equatorial Pacific (Fig. 4a), indicative of a weak-moderate El Niño. The ensemble GloSea forecast for the Niño3.4 region SST anomaly, from the June prediction, is shown in Fig. 5, along with verification to October. The overall observed warming trend is generally well captured by the ensemble. Although the 'plateau' between July and September is not captured, the observed SST anomalies lie within the envelope of uncertainty expressed by the dispersion in the ensemble.

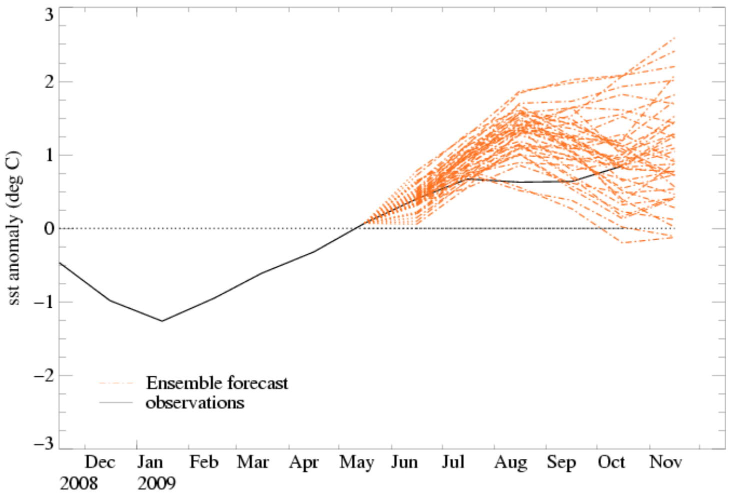


***Figure 5.*** *Observed (black) and June predicted (41 members, red) SST anomalies for the Niño3.4 region in the tropical Pacific Ocean. Anomalies are expressed relative to the 1987–2001 period. The spread in the ensemble members is an indication of the degree of uncertainty.*

## 3.4 Observed vertical wind shear in the North Atlantic

El Niño conditions are associated with positive anomalies in vertical wind shear in the North Atlantic, which in turn creates unfavourable conditions for tropical storm development and maintenance (Zehr, 1992; Landsea *et al.*, 1998). During much of August–October 2009, wind shear across the Caribbean Sea and southwest tropical Atlantic was anomalously high (Fig. 6) and will have contributed to the below-normal activity during the period; 8 tropical storms formed during August–October with a combined ACE index of 44.7, compared to the 1990–2005 average of 10.1 and 108.0, respectively.

September, the month with peak climatological activity, was particularly quiet this season, with only 2 tropical storms and a monthly ACE index of 11.5, compared to 1990–2005 averages of 3.8 and 51.6, respectively. The low activity is consistent with positive anomalies in vertical wind shear which were more widespread across the tropical North Atlantic in September than in August or October (Fig. 6). Negative wind shear anomalies were only observed in parts of the MDR, temporarily providing favourable conditions for the development of hurricane Fred which briefly attained category 3 status in this region before succumbing to vertical wind shear.

Positive wind shear anomalies observed in the western MDR and Caribbean regions during August–October 2009 may be contrasted with the negative vertical wind shear anomalies observed in a similar region in 2008, when above-normal tropical storm activity was observed (Fig. 7).

The impact of the anomalously high vertical wind shear on individual storms is illustrated in the satellite ‘snapshots’ in Fig. 8. Nine of the eleven tropical depressions that formed in 2009 were sheared apart, as shown by the exposed low-level circulations and convection well removed from the low-level centres. Four of these storms (Claudette, Danny, Erika, Henri) dissipated over the tropical North Atlantic within four days (Fig. 9). This season only two tropical storms (Grace, which formed to the northeast of the Azores, away from the tropics, and hurricane Bill) were not subject to high vertical wind shear at some stage in their lifetimes.

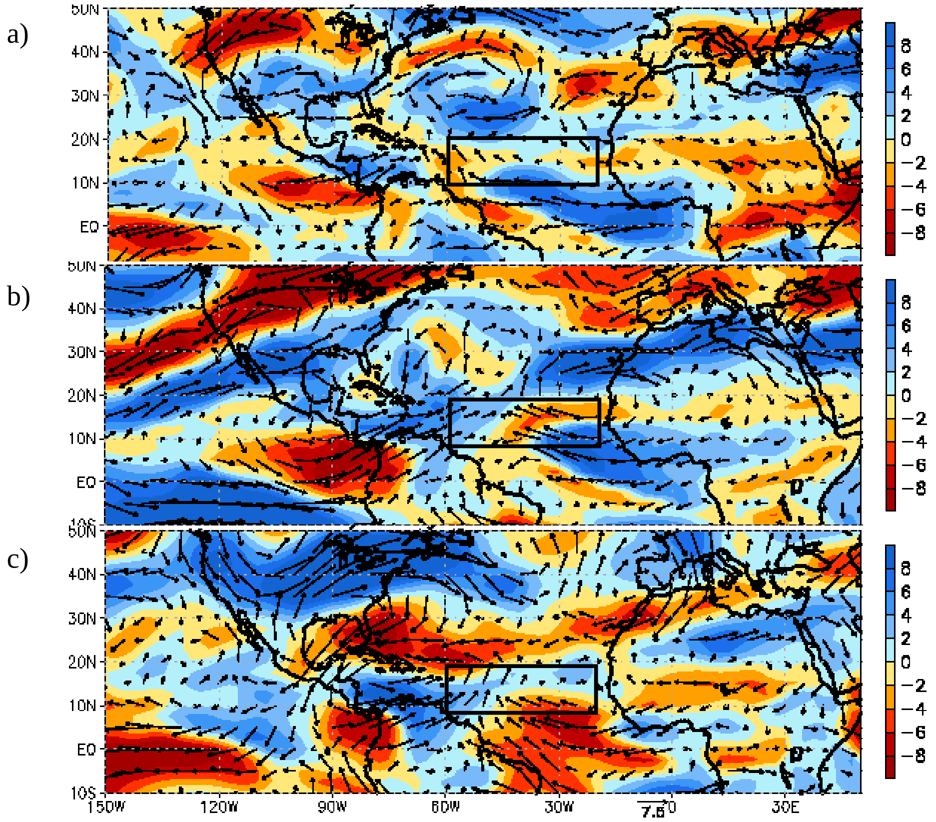


***Figure 6.*** *31-day mean vertical wind shear anomalies between the 200hPa and 850hPa pressure levels for (a) 1st –31st August, (b) 1st September–1st October and (c) 1st–31st October. Anomalies are expressed relative to the 1971–2000 average. The North Atlantic Main Development Region is shown boxed. Image produced using the Climate Prediction Centre/NCEP hurricane monitoring data [http://www.cpc.noaa.gov/products/hurricane/](http://www.cpc.noaa.gov/products/hurricane/).*

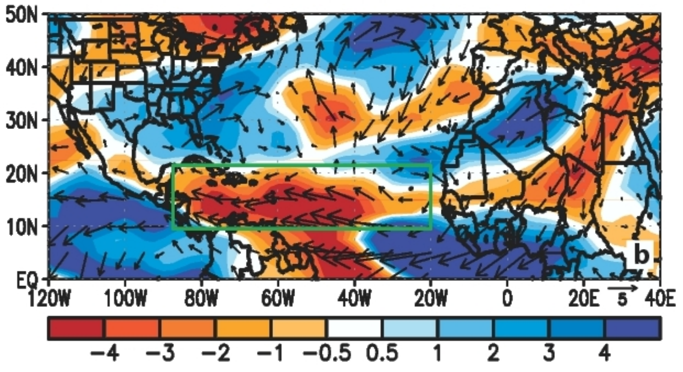


***Figure 7.*** *As Fig. 6, but averaged for the 3-month period August-September-October 2008. (From Bell et al. 2008)*

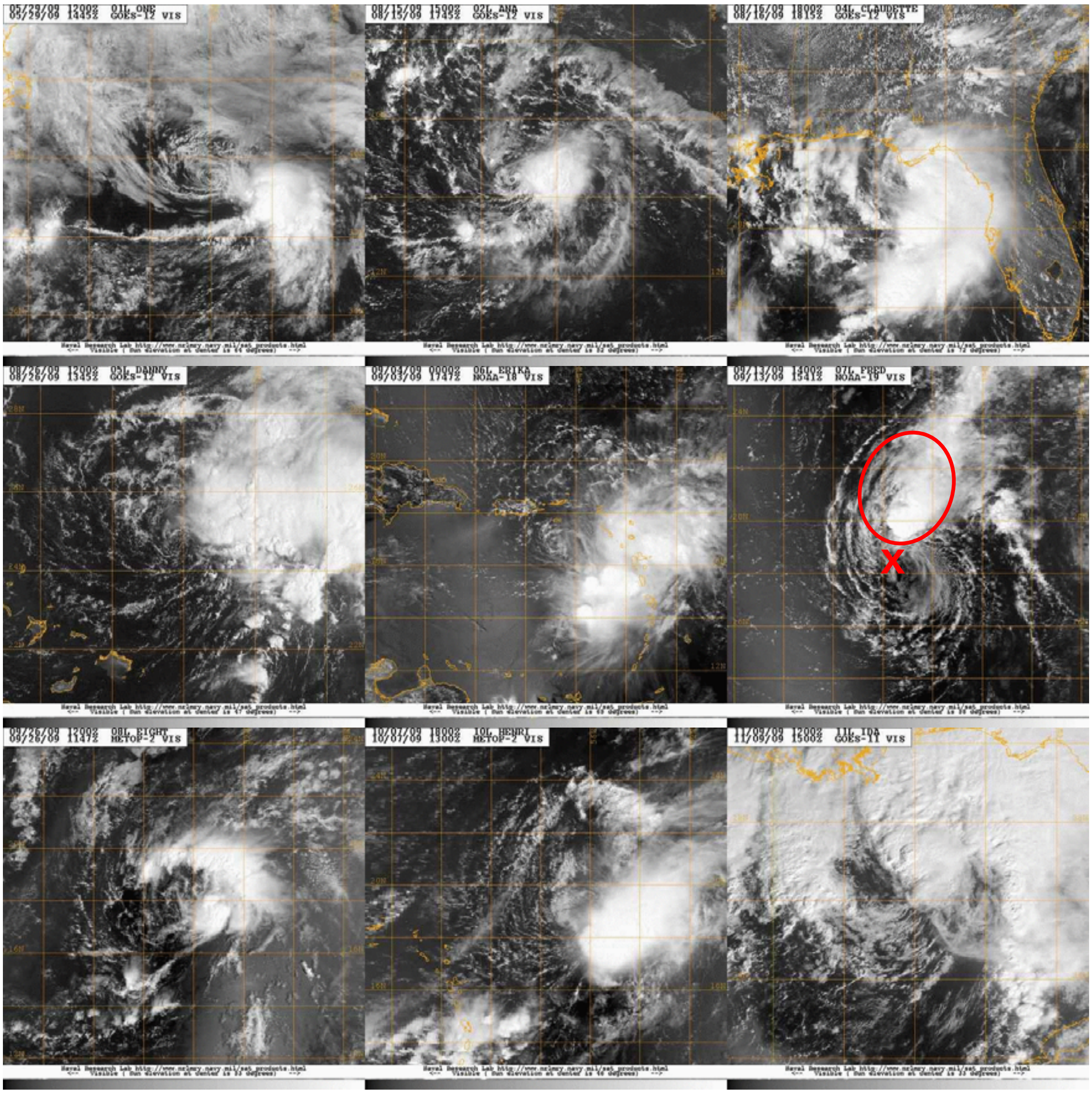

***Figure 8.*** *Satellite imagery for 9 of the 11 tropical depressions observed in the 2009 season, illustrating the effects of strong wind shear present over the tropics. Left to right and top to bottom; TD1, Ana, Claudette, Danny, Erika, Fred, TD8, Henri and Ida. An example of convection (circled) removed from low-level circulation centre (x) is shown for tropical storm Fred. Images courtesy of US Naval Research Laboratory ([http://www.nrlmry.navy.mil/TC.html](http://www.nrlmry.navy.mil/TC.html)).*

## 3.5 Met Office tropical storm forecasts from other lead times

Deterministic predictions of 2009 tropical storm activity generated at monthly intervals from March through to August are provided, along with their verification (where the forecast period has completed) in Table 3. Each prediction is for the total number of tropical storms and ACE index for months 2–6 in the forecast. The forecasts have consistently indicated below-normal activity, with best estimates below the 1990–2005 climatological average for both tropical storm numbers and ACE index from all start months. The predictions generated each month from March to June are now verifiable. All these forecasts gave accurate guidance, both for storm numbers and ACE index, in terms of indicating below normal activity over the target periods. Observed activity was within the range predicted in all cases except for the May prediction of ACE index for June–October, when the observed index was just below the range predicted.

As a guide to the relative performance track record of forecasts from the different start months, linear correlations between observed and predicted values of tropical storm numbers and ACE index are shown in Table 4. Correlations are positive in all forecasts except for those initialised in March, with largest correlations for the June forecasts (both for numbers of tropical storms and ACE index).

| Forecast month | Period of forecast | Tropical storms | | ACE index | |
|---|---|---|---|---|---|
| | | Forecast | Observed | Forecast | Observed |
| March | April – August | 3 (1–5) | 4 (5.6) | 20 (10–30) | 29.1 (54) |
| April | May – September | 6 (3–9) | 6 (9.5) | 53 (36–70) | 40.1 (108) |
| May | June – October | 7 (4–11) | 8 (11.9) | 70 (46–94) | 44.7 (127) |
| June | July – November | 6 (3–9) | 9 (12.4) | 60 (40–80) | 52.4 (131) |
| July | August – December | 8 (5–11) | -- (10.6) | 75 (55–96) | -- (121) |
| August | September – January | 4 (2–7) | -- (7.4) | 36 (12–60) | -- (74) |

***Table 3.*** *GloSea-predicted best estimate and two-standard-deviation range for numbers of tropical storms and ACE index from forecasts initialised at monthly intervals from March to August 2009. Observed figures are provided only where the forecast period has completed. Observed figures in brackets correspond to the 1990–2005 climatological average.*

| Forecast month | Period of forecast | Linear Correlation | |
|---|---|---|---|
| | | Tropical storms | ACE index |
| March | April – August | -0.45 | -0.24 |
| April | May – September | 0.43 | 0.48 |
| May | June – October | 0.33 | 0.30 |
| June | July – November | 0.63 | 0.70 |
| July | August – December | 0.46 | 0.69 |
| August | September – January | 0.12 | 0.31 |

***Table 4.*** *Linear correlation between the predicted number of tropical storms and ACE index with observed values from NOAA's HURDAT dataset during the period 1987–2008.*

## 4. Seasonal forecasts of 2009 North Atlantic tropical storm activity from other centres

Seasonal forecasts of 2009 North Atlantic tropical storm activity issued by other forecast centres may be compared with the Met Office forecast in Table 5. Predictions are based on statistical forecasting methods, for example Colorado State University (CSU), Tropical Storm Risk (TSR) and the National Oceanic and Atmospheric Administration (NOAA), and dynamical predictions systems such as the European Centre for Medium Range Weather Forecasts (ECMWF) and the EUROSIP multi-model (a combination of ensemble forecasts from the Met Office, ECMWF and Météo-France prediction systems). Statistical forecasts are for predictions of tropical storm numbers and ACE index over the June to November period; dynamical forecasts from the Met Office and EUROSIP are for the period July to November and forecasts from ECMWF are for the period July to December.

The observed activity was within the range predicted for all the June issued forecasts – both statistical and dynamical (for the forecasts that stated a range). In general, the best estimates from the statistical methods predicted higher activity than those from the dynamical systems. The longer-lead forecasts available from the statistical methods tended to over-estimate the level of activity, with observed values below the predicted range. The mid-season update from TSR also overestimated the observed activity.

| Centre | Date of issue | Tropical storms | ACE index |
|---|---|---|---|
| CSU | 10th December 2008 | 14 | 125 |
| | 7th April 2009 | 12 | 100 |
| | 2nd June 2009 | 11 | 85 |
| | 4th August 2009 | 10 | 80 |
| TSR | 5th December 2008 | 14.8 (±4.3) | 136 (±60) |
| | 6th April 2009 | 15 (±3.8) | 135 (±56) |
| | 4th June 2009 | **10.9 (±3.3)** | **69 (±50)** |
| | 6th July 2009 | **11.4 (±3.2)** | **80 (±46)** |
| | 4th August 2009 | 12.6 (±2.8) | 105 (±40) |
| NOAA* | 21st May 2009 | **9–14** | 57–114 |
| | 6th August 2009 | **7–11** | **52–96** |
| Met Office | 18th June 2009 | **6 (3–9)** | **60 (40–80)** |
| ECMWF | June 2009 | **8.1 (±2.6)** | **40 (±20)** |
| EUROSIP | June 2009 | **6.3 (±2.8)** | -- |

***Table 5.*** *Seasonal forecasts of 2009 North Atlantic tropical storm activity from Colorado State University (CSU), Tropical Storm Risk (TSR), National Oceanic and Atmospheric Administration (NOAA), the Met Office, the European Centre for Medium Range Weather Forecasts (ECMWF), and the EUROSIP multi-model system. The Met Office and EUROSIP seasonal forecasts are for the period July–November only, the ECMWF forecast is for the July to December period. ECMWF and EUROSIP forecasts are available through the Met Office and other ECMWF member states. *Values quoted for NOAA are based on predicted percentages of the 1951–2000 median of 87.5. Forecasts are highlighted in bold where the observed activity was within the predicted range.*

## 5. Summary of individual storms

A summary of named tropical storms in the 2009 North Atlantic hurricane season is shown in table 6, and corresponding storm tracks are shown in Fig. 9. The 2009 North Atlantic hurricane season started early on the 28th May with the development of tropical depression one (winds < 39 mph) off the coast of North Carolina. No named storms, however, formed in May, June or July. The last time that no tropical storm activity occurred during this period was in 2000. The formation of tropical storm Ana on the 15th August is the latest date that the first named tropical storm of the season has formed in the Atlantic basin since Hurricane Andrew in 1992. The formation of Ana was followed later that day by tropical storm Bill near the Cape Verde Islands. Bill became the first hurricane and major hurricane of the season, with peak wind speeds of 135 mph (category 4 on the Saffir-Simpson scale) and a minimum central pressure of 943 hPa. Bill passed the south coast of Nova Scotia on the 23rd August, causing significant disruption to power supplies, before making landfall in Newfoundland on the 24th August with maximum wind speeds of 69 mph. Major hurricane Bill became the strongest and longest-lived storm of the 2009 hurricane season, lasting 10 days and generating 51% of the seasonal ACE index.

| Storm name | Active dates | Category | Max wind speed (mph) | Min central pressure (hPa) | ACE index |
|---|---|---|---|---|---|
| Ana | 11–16th August | TS | 40 | 1003 | 0.98 |
| Bill | 15–24th August | MH 4 | 135 | 943 | 26.47 |
| Claudette | 16–18th August | TS | 50 | 1006 | 0.41 |
| Danny | 26–29th August | TS | 60 | 1006 | 2.29 |
| Erika | 1–3rd September | TS | 60 | 1004 | 1.42 |
| Fred | 7–12th September | MH 3 | 120 | 958 | 10.47 |
| Grace | 4–6th October | TS | 70 | 986 | 1.41 |
| Henri | 6–8th October | TS | 50 | 1005 | 1.22 |
| Ida | 4–10th November | H2 | 105 | 976 | 7.72 |

***Table 6.*** *Observed 2009 North Atlantic tropical storm activity. The storm category 'TS' (tropical storm), 'H' (hurricane; categories 1–2) and 'MH' (major hurricane; categories 3–5), is based on the Saffir-Simpson hurricane scale (Simpson, 1974). Observed ACE index values are from http://www.coaps.fsu.edu/~maue/tropical/. Units of ACE index are $10^4$ $kt^2$.*

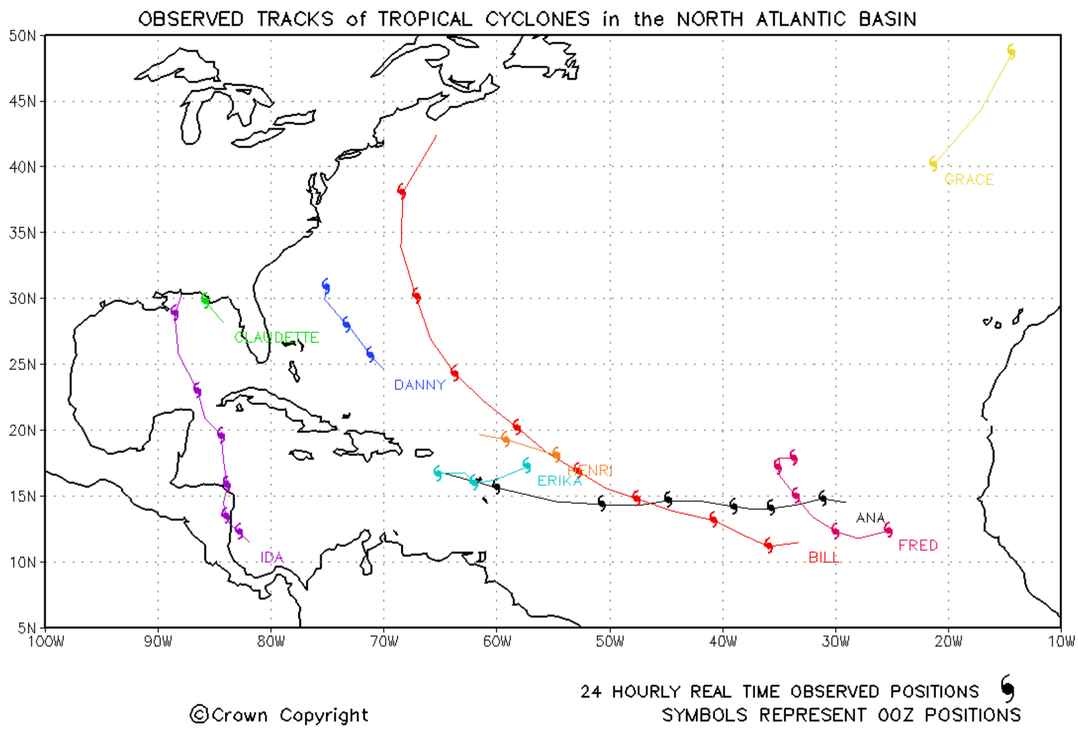


**Figure 9.** *Observed tracks for all North Atlantic tropical storms during 2009.*

On the 16th August, tropical storm Claudette formed in the Gulf of Mexico to the south of Tallahassee, Florida. Claudette was the first storm of the 2009 season to make landfall in the USA, impacting Santa Rosa Island, Florida, with winds of 50 mph. The fourth named storm of the season, tropical storm Danny, formed to the east of the Bahamas on the 26th August and reached peak wind speeds of 60 mph before merging with a frontal system off the North Carolina coast.

Tropical storm Erika was the first of only two tropical storms to form in September. The last season with 2 or fewer tropical storms in September was in 1996 when 2 tropical storms were also recorded. Tropical storm Erika formed near the Lesser Antilles on 1st September but was only able to sustain tropical storm strength for 3 days due to strong vertical wind shear. Erika passed over the island of Guadaloupe on the 2nd September, with maximum wind speeds of 39 mph. The second storm to form in September was tropical storm Fred. Fred originated from an intense tropical wave to the south of the Cape Verde Islands on the 7th September and rapidly intensified into a major hurricane, attaining maximum sustained wind speeds of 120 mph and a minimum central pressure of 958 hPa on the 9th September. Major hurricane Fred became the second strongest storm of the 2009 season and the strongest recorded hurricane south of 30°N and east of 35°W since satellite based classifications of tropical storm intensity began in 1972. Fred dissipated as a tropical storm in the eastern Atlantic on the 12th September; however, thunderstorm activity associated with the remnants of tropical storm Fred later impacted the southeast coast of the United States.

Tropical storm Grace was one of only two short-lived tropical storms to form in October. Grace formed to the northeast of the Azores Islands on the 4th October with maximum wind speeds reaching 70 mph before merging with a frontal system in the northwestern Atlantic on the 6th October. The remnants of Grace later impacted southern Ireland and the United Kingdom. Tropical storm Henri formed on the 6th October to the east of the Leeward Islands. Henri reached peak wind speeds of 50 mph before dissipating on the 8th October as it moved into a region of cooler ocean waters and high vertical wind shear.

Tropical storm Ida was the last named storm of the 2009 season, forming on the 4th November near the coast of Costa Rica in the southwest Caribbean Sea. Ida became the third hurricane of the 2009 season, reaching maximum wind speeds of 75 mph before making its first landfall in eastern Nicaragua. After a period of weakening as Ida passed over Nicaragua and Honduras, Ida re-emerged into the Caribbean Sea, tracked into the Gulf of Mexico and re-intensified into a category 2 hurricane on the 8th November, with winds of 105 mph, before making landfall as a tropical storm over Dauphin Island and Bon Secour, Alabama, on the 10th November.

No hurricanes made landfall in the USA during 2009 and no category 5 hurricanes occurred.

## 6. Changes to the GloSea forecasting system

From June 2010 seasonal forecasts of tropical storm activity for the North Atlantic will be produced using a new upgraded seasonal forecasting system, GloSea4. This system uses the new Met Office Hadley Centre coupled ocean-atmosphere climate model HadGEM3, which has improved flow dynamics and representation of physical processes. In addition, the system has enhanced atmospheric horizontal resolution of 1.875° east-west by 1.25° north-south (compared, respectively, to 3.75° x 2.5° for the present system used for the 2009 forecast) and enhanced vertical resolution (38 vertical levels compared to 19 for the current system). In recognition of the growing importance of seasonal prediction, the new system is fully integrated within the development cycle of the Met Office family of models, meaning that the development and performance of the system will benefit from improvements in models at all timescales — giving good potential for improving the skill of seasonal forecasts of tropical storm activity over the North Atlantic.

## 7. Summary

The Met Office seasonal tropical storm forecast for the North Atlantic, issued on the 18th June 2009, predicted below-normal activity for the July to November 2009 period, with a best estimate of 6 tropical storms (with a range 3–9) and an ACE index of 60 (range 40–80). In addition the forecast indicated a very high probability (~100%) of fewer storms than the 15 observed in 2008, and a high probability (65.9%) of an ACE index of 60 (the best estimate) or less, compared to a climatological chance of 22.7%. The forecasts therefore gave a strong indication for the quietest July to November period for more than a decade; the last season with 6 or fewer tropical storms was in 1992 (6) and the last season with an ACE index of 60 or less was in 1997 (38.8).

In the event the observed number of storms (9) and the observed ACE index (52.4) were both within the predicted ranges, and well below the 1990–2005 July–November averages of 12.4 and 131 respectively. Thus in terms of ACE index the season was indeed the quietest for over a decade. In terms of tropical storm numbers only the 2006 season has recorded 9 or fewer tropical storms in the last decade (9 storms were observed in the July to November period 2006).

The observed below-normal activity was also evident in the low numbers of storms reaching hurricane strength. Three hurricanes and 2 major hurricanes formed during 2009, compared to the 1990–2005 averages of 7.2 and 3.1, respectively. The last season with 3 or fewer hurricanes was in 1997, when 3 hurricanes occurred. The strongest storm of the season (Bill) reached maximum sustained wind speeds of 135 mph and alone generated 51% of the seasonal ACE index. Two tropical storms made landfall along the coast of the USA (Ida and Claudette). Neither of these made landfall at hurricane strength.

An assessment of predicted SST anomalies in the tropical Pacific concluded that the observed development of weak-to-moderate El Niño conditions was generally well captured by the GloSea forecast ensemble. Although most ensemble members overestimated the degree of warming, the observed SST evolution is contained within the predicted envelope of uncertainty. For the North Atlantic, the forecast SSTs were cooler than observed.

Evidence has been presented to support relatively strong vertical wind shear, particularly in the western Main Development Region and over the Caribbean, as a key factor in the observed below-normal activity. Strong vertical wind shear in the tropical North Atlantic is known to be associated with El Niño events, and the GloSea-predicted El Niño development is therefore likely to have been crucial in the successful prediction of below-normal North Atlantic tropical storm activity.

## Appendix A – Retrospective forecasts for the 2005–2008 seasons

Re-forecasts for the last four Atlantic seasons (July to November) are provided here for comparison with the 2009 forecast. The re-forecasts have been made using the same method as for the 2009 forecast, with the exception that a smaller 15-member ensemble is used for the 2005 forecast, rather than the 41-member ensemble used since 2006. Only information that would have been available in an operational real-time environment has been used. Because of small changes to the calibration method this year, the values differ in some instances from those provided in last year's forecast report and in the 2007 and 2008 operational forecasts.

For 2008 the ensemble-mean prediction of 15 storms exactly matches the number of observed storms. In contrast, the ensemble-mean prediction for ACE index is too high, with the observed value of 144 below the predicted range of 154–206 (Table 7). The probability forecasts give accurate guidance in favouring activity greater than the climate mode, both for tropical storm numbers and for ACE index (Figs. 10a and b). However, the most likely category overestimates the observed activity in both cases.

| | Number of storms | | | ACE index | | |
|---|---|---|---|---|---|---|
| | EM | 2 sd range | Observed | EM | 2 sd range | Observed |
| 2008 | 15 | 11–19 | 15 | 180 | 154–206 | 144 |
| 2007 | 9 | 6–13 | 12 | 81 | 61–102 | 71 |
| 2006 | 13 | 10–17 | 9 | 136 | 112–161 | 76 |
| 2005 | 18 | 8–29 | 25 | 174 | 114–235 | 239 |

***Table 7****: Ensemble mean (EM) forecasts and observations for 2005–2008 July to November tropical storm numbers and ACE index. Forecasts are initialised in June and are made using identical methods to those used for the 2009 forecast. (Note the 2005 forecast used a smaller ensemble of 15 members.) Also, the ensemble-mean values and two-standard-deviation ranges for 2007 and 2008 differ, in some cases, from the values issued operationally because of small changes to the forecast calibration. Storm numbers and ACE index are derived from the NOAA HURDAT dataset and may differ from values published with our public website forecast.*

For 2007 the observed number of storms (12) was within the two-standard-deviation forecast range of 6–13 (Table 7). The 2007 season was notable for the relatively low ACE index considering the near-normal number of storms that occurred – resulting from a predominance of relatively weak short-lived storms. The observed low ACE index (71) was within the predicted range of 61–102 (Table 7), and the potential for a low value was clearly indicated in the probability forecast for ACE index (Fig. 11b), which showed an enhanced probability (nearly twice the climatological chance) of an ACE index of less than 70.

The contrast between the exceptionally active 2005 season (25 storms observed) and the near-average 2006 season (9 storms observed) was well captured by the forecast probability distributions. For 2005 the peak in forecast probability distribution is in the >21 category (Fig. 13a), while for 2006 the peak forecast probability is for the 7–9 category (Fig. 12a). Thus in both years the category predicted as most likely was observed. The observed difference between the 2005 and 2006 seasons is also captured, to a degree, in the ACE index forecasts. For 2005 (Fig. 13b), the largest predicted probability is for the 100–129 ACE index category, but there is a strong secondary peak for the >219 category (the observed value was 239). In contrast, predicted probabilities for the 2006 season (Figs. 12b) show little skew and the 70–99 category (which contains the observed value of 76) had the highest predicted probability (and largest predicted enhanced chance over the climatological chance).

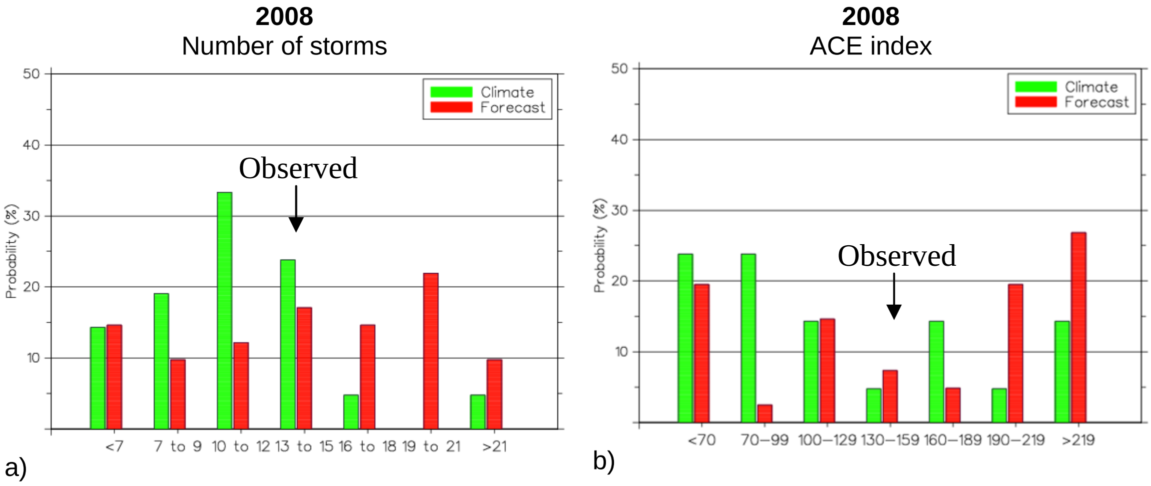


***Figure 10**: a) Forecast probability that the number of Atlantic sector tropical storms, in the July to November 2008 period, will lie within given ranges. Red bars indicate the forecast probabilities for 2008; green bars the climatological frequencies derived from the NOAA HURDAT observation dataset, 1987–2007. b) As a), but for ACE index. Observed categories for the number of tropical storms and ACE index were 13–15 and 130–159, respectively.*

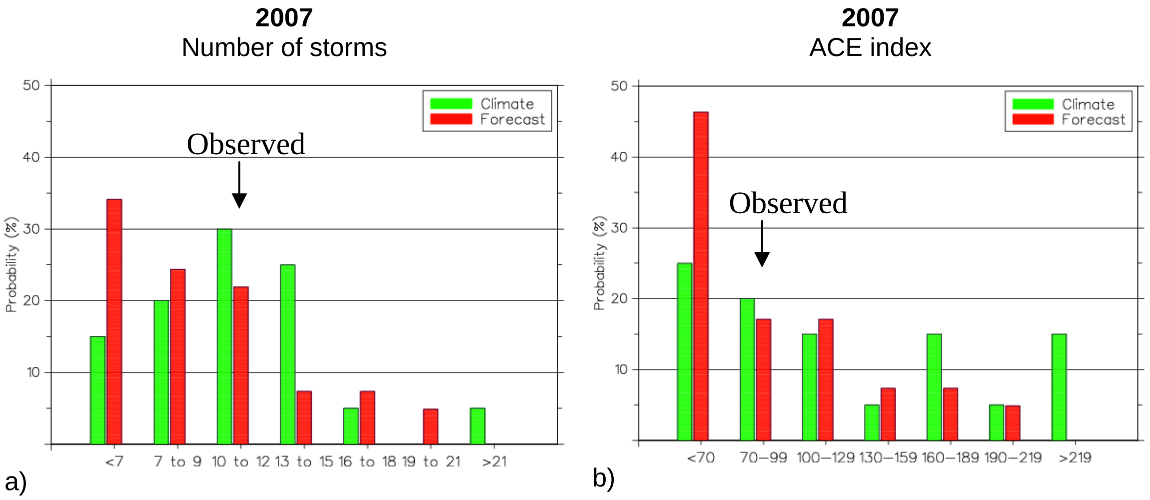


***Figure 11**: As Fig. 9, but for 2007. Climatological frequencies are based on 1987–2006. Observed categories for the number of tropical storms and ACE index were 10–12 and 70–99, respectively.*

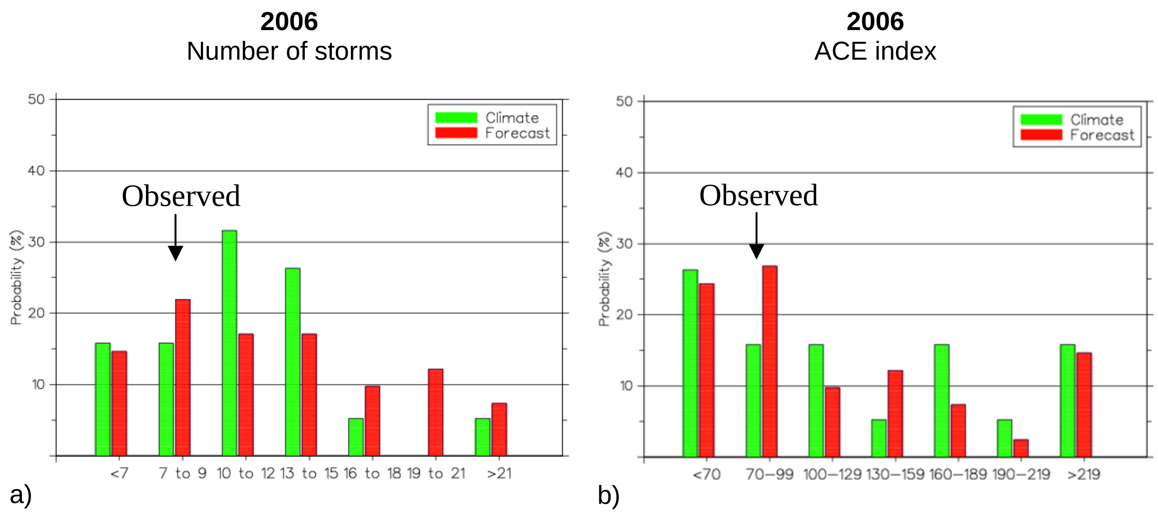


***Figure 12****: As Fig. 9, but for 2006. Climatological frequencies are based on 1987–2005. Observed categories for the number of tropical storms and ACE index were 7–9 and 70–99, respectively.*

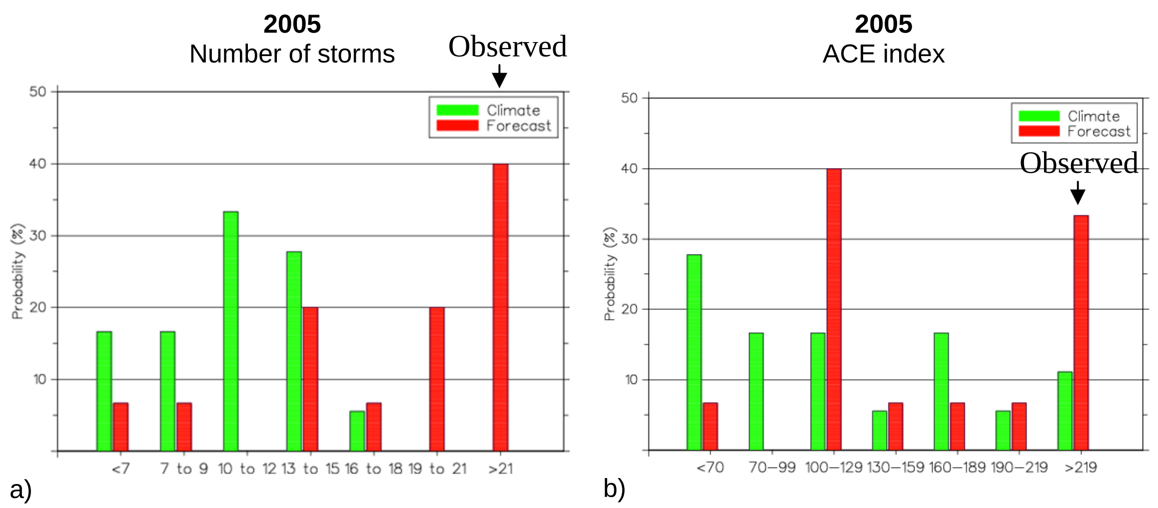


***Figure 13****: As Fig. 9, but for 2005. Climatological frequencies are based on 1987–2004. Observed categories for the number of tropical storms and ACE index were >21 and >219, respectively.*

## References

Bell, G., Blake, E., Goldenberg, S., Kimberlain, T., Landsea, C., Pasch, R., Schemm, J. (2008). The 2008 North Atlantic hurricane season a climate perspective.
www.cpc.noaa.gov/products/expert_assesment/hurrsummary_2008.pdf

Bell, G. D., Halpert, M. S., Schnell, R.C., Higgins, R.W., Lawrimore, J., Kousky, V.E., Tinker, R., Thiaw, W., Chelliah, M., Artusa, A. (2000). Climate assessment for 1999. *Bull. Amer. Meteor. Soc.*, **81** (June), S1–S50.

Goldenberg, S. B., Landsea, C. W., Mestas-Nuñez A. M. and Gray, W.M. (2001). The recent increase in Atlantic hurricane activity: causes and implications. *Science*, **293**, 474–479.

Gray, W.M. (1984). Atlantic seasonal hurricane frequency. Part I: El Niño and 30 mbar quasi-biennial oscillation influences. *Mon. Wea. Rev*., **112**, 1649–1668.

Landsea, C. W., G. D. Bell, W. M. Gray, and S. B. Goldenberg (1998). The extremely active 1995 Atlantic Hurricane season: Environmental conditions and verification of seasonal forecasts, *Mon. Wea. Rev*., **126**, 1174–1193.

Simpson, R. H (1974). The hurricane disaster potential scale. *Weatherwise*, 27, 169–186.

Vitart, F. and Stockdale, T. N. (2001) Seasonal forecasting of tropical storms using coupled GCM integrations, *Mon. Wea. Rev*., **129**, 2521–2537.

Vitart, F (2006). Seasonal forecasting of tropical storm frequency using a multi-model ensemble. *Quart. J. Roy. Meteor Soc*., **132**, 647–666.

Vitart, F., M. R. Huddleston, M. Déqué, D. Peake, T. N. Palmer, T. N. Stockdale, M. K. Davey, S. Ineson, and A. Weisheimer (2007). Dynamically-based seasonal forecasts of Atlantic tropical storm activity issued in June by EUROSIP, *Geophys. Res. Lett*., **34**, L16815.

Zehr, R. M (1992). Tropical cyclogenesis in the Western North Pacific. NOAA Tech. Rep. NESDIS 61, NOAA, 181pp. [Available from NOAA/NESDIS/CIRA, Fort Collins, CO 80523.)

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