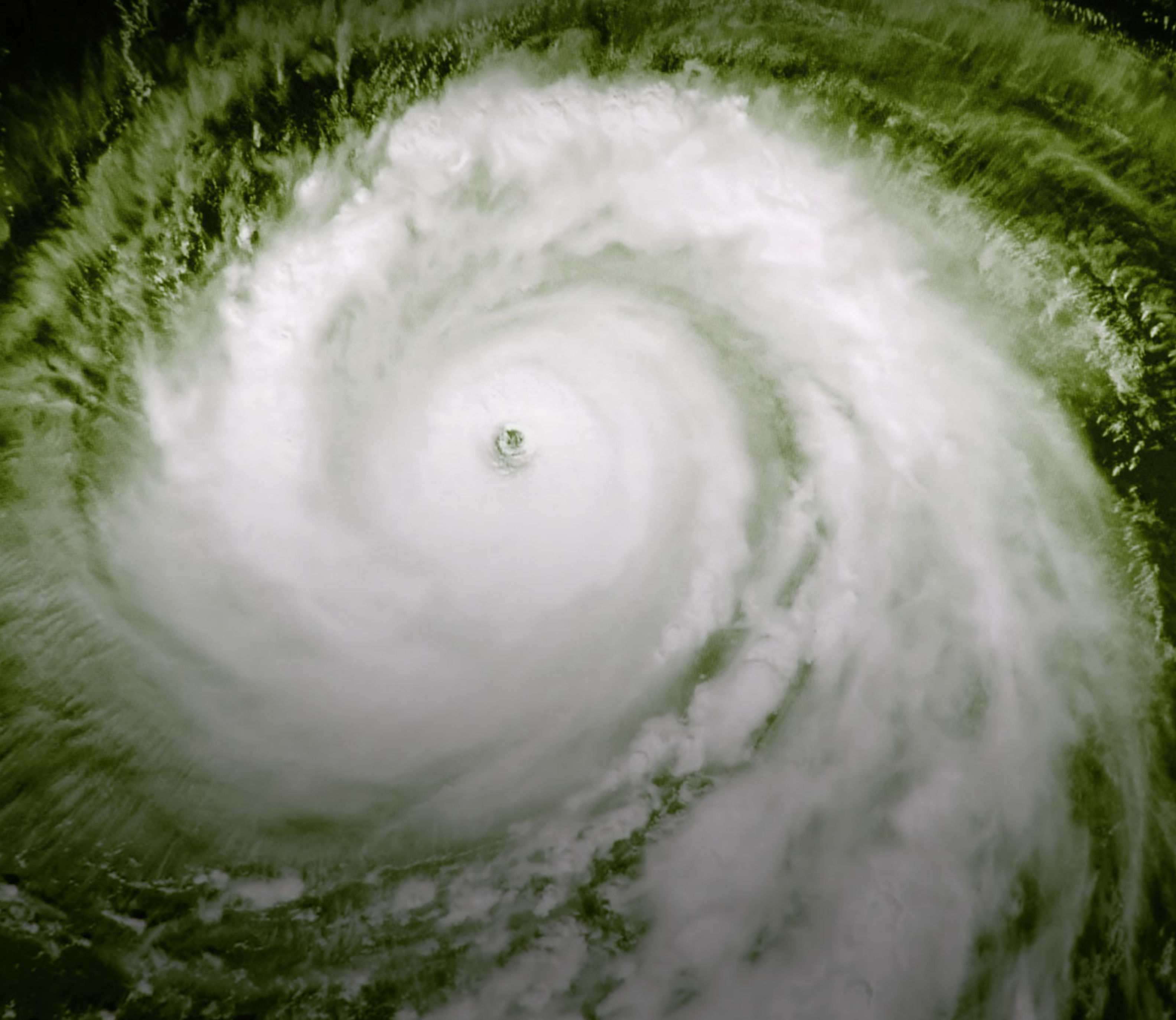
Outlook

Seasonal Tropical Storm Outlook for the North Atlantic

May 2011



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SEASONAL TROPICAL STORM OUTLOOK FOR THE NORTH ATLANTIC JUNE–NOVEMBER 2011

ISSUED MAY 2011

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Seasonal Tropical Storm Outlook for the North Atlantic: June–November 2011

Issued May 2011

SUMMARY:

The latest seasonal forecast indicates near- to above-normal tropical storm activity in the North Atlantic during June–November 2011.

The dynamical model prediction is for 13 tropical storms as the most likely number during June–November 2011, with a two-standard-deviation range of 10–17.

The most likely predicted ACE index is 151, with a two-standard-deviation range of 89–212.

Seasonal prediction skill at this range is modest, with linear correlations of 0.49 for predictions of tropical storm numbers and 0.25 for predictions of ACE index.

The large range around the best-estimate forecast is indicative of large uncertainty – a consequence of the uncertainty in predictions for ENSO, a key driver of tropical storm activity in the North Atlantic. Both the Met Office and ECMWF forecasting systems predict recovery from below-normal sea surface temperatures (La Niña conditions) in the tropical Pacific, but at different rates. This results in any of La Niña, neutral or El Niño conditions potentially possible by the peak of the hurricane season.

The estimates for June–November 2011:

- a 4.7% chance of exceeding 19 storms (recorded June–November 2010).
- a less than 1% chance of exceeding 27 storms (recorded June–November 2005).

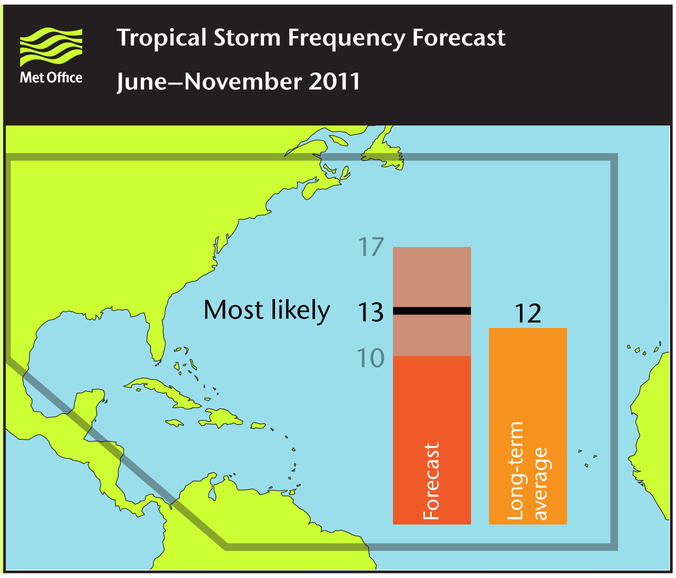
Tropical Storm Forecast for June-November 2011

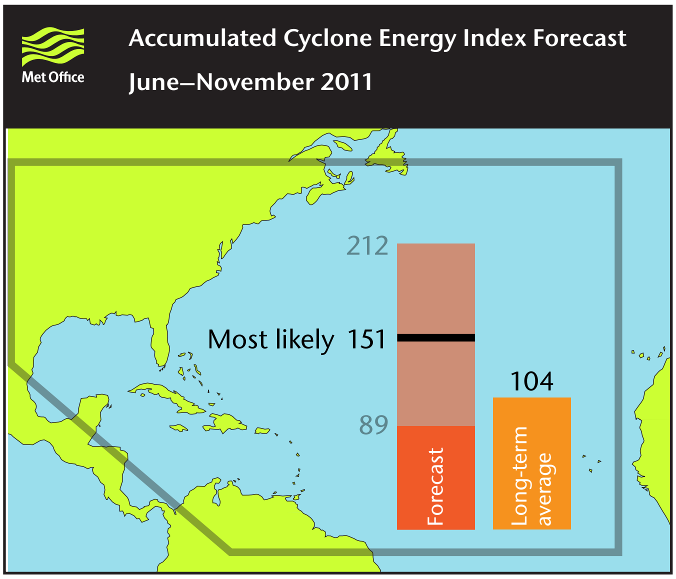
FORECAST:

The most likely number of tropical storms predicted to occur in the North Atlantic basin during June–November 2011 is 13, with a two-standard-deviation range of 10–17. This represents near-normal activity relative to the 1980–2010 long-term average of 12.

The most likely predicted ACE index is 151, with a two-standard-deviation range of 89–212. This represents above-normal activity relative to the 1980–2010 average of 104.

The tropical storm frequency and ACE index forecasts are based on combined output from the Met Office and ECMWF seasonal forecasting systems. A description of the forecast methodology is available at the end of this report.





Supporting Information

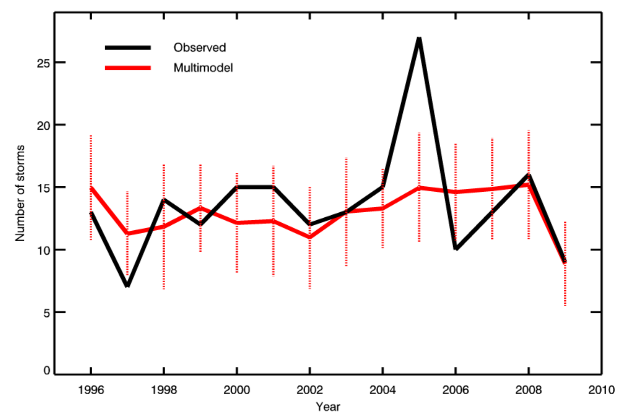
Deterministic Forecast Verification June–November 2011

Verification is presented for May predictions of numbers of tropical storms and ACE index for the period June–November. Verification is for ensemble-mean predictions from the combined Met Office and ECMWF ensemble for the retrospective period 1996–2009. For retrospective forecasts the multi-model ensemble size is 23. The vertical bars on the graphs represent ± 1 standard deviation about the ensemble mean.

Prediction skill for forecasts initialised in May is modest. Linear correlations between predictions and observations are 0.49 for tropical storm numbers and 0.25 for ACE index.

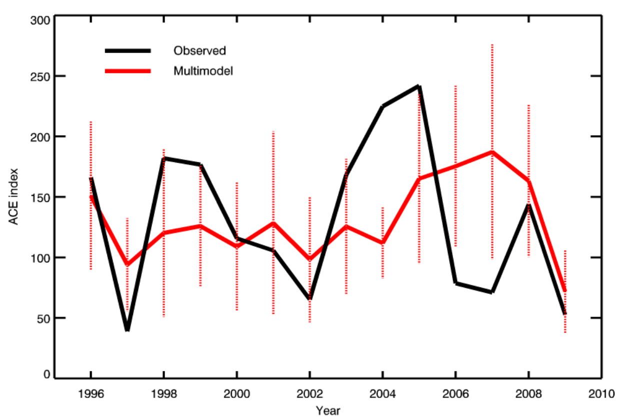
Linear correlation measures the strength of the linear relationship between forecasts and observations; it takes values between -1 and 1 (zero indicates no linear relationship between the datasets).

Tropical Storm Frequency June–November 1996–2009



Linear correlation: 0.49

Accumulated Cyclone Energy (ACE) Index June–November 1996–2009



Linear correlation: 0.25

Probabilistic Forecasts

Tropical Storm Frequency

Probability forecast information is derived from the combined 83-member Met Office and ECMWF seasonal forecast ensemble. The probability distribution function (PDF) provides the forecast probability (red) that the number of storms will be within discrete ranges. The cumulative distribution function (CDF) provides forecast probabilities (red) for exceeding a given number of storms. The distribution has not been smoothed or fitted to a functional form. Observed numbers of tropical storms for the period 1980–2010 (blue) are calculated from the NOAA Hurricane Database (HURDAT). The observed categories over the last 6 years are indicated on the graph.

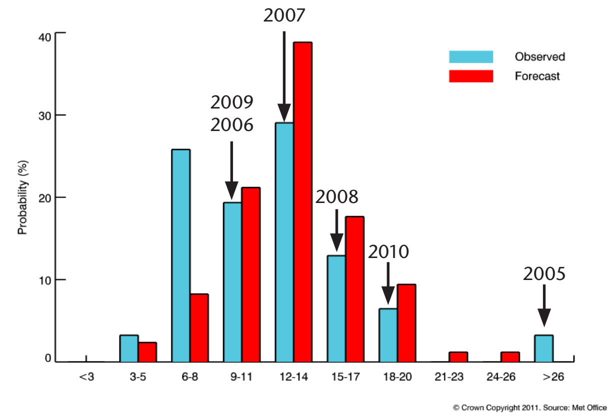
The probability distribution for the number of tropical storms predicted for June–November 2011 shows a slight enhancement relative to climatology for near-normal and high activity categories (for example 15–17 and 18–20 tropical storms) and decreased probability for low activity categories (for example 3–5 and 6–8 tropical storms).

The predicted probability of exceeding the number of storms observed in a selection of past years (June–November) is given below:

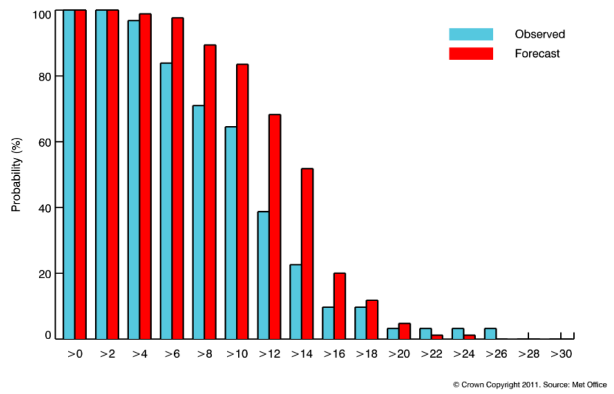
- probability of exceeding 19 storms (2010) is 4.7% compared to a climate chance of 3.2%.
- probability of exceeding 9 storms (2009) is 89.4% compared to a climate chance of 67.7%.
- probability of exceeding 27 storms (2005) is the same as the climate chance of less than 1%.

Met Office

Tropical Storm Frequency
June–November 2011



PDF: Probability that the number of tropical storms will lie within given ranges



CDF: Probability that the number of tropical storms will exceed a given number

Climate and forecast probabilities that the number of tropical storms will exceed a given threshold. Note: probabilities are given to one decimal place to help preserve a smooth distribution. Accuracy to one decimal place is not implied.

Number of tropical storms	Climate probability 1980–2010	Forecast probability 2011
> 0	100.0	100.0
> 1	100.0	100.0
> 2	100.0	100.0
> 3	100.0	100.0
> 4	96.8	98.8
> 5	96.8	98.8
> 6	83.9	97.6
> 7	77.4	94.1
> 8	71.0	89.4
> 9	67.7	89.4
> 10	64.5	83.5
> 11	51.6	71.8
> 12	38.7	68.2
> 13	29.0	51.8
> 14	22.6	51.8
> 15	12.9	29.4
> 16	9.7	20.0
> 17	9.7	15.3
> 18	9.7	11.8
> 19	3.2	4.7
> 20	3.2	4.7
> 21	3.2	2.4
> 22	3.2	1.2
> 23	3.2	1.2
> 24	3.2	1.2
> 25	3.2	0.0
> 26	3.2	0.0
> 27	0.0	0.0
> 28	0.0	0.0
> 29	0.0	0.0
> 30	0.0	0.0

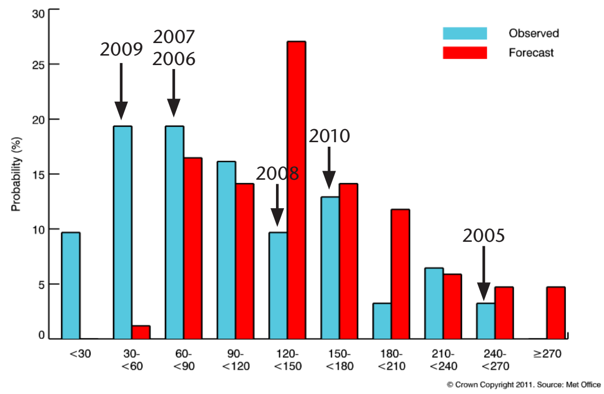
Accumulated Cyclone Energy (ACE) Index

The forecast probability distribution for ACE index shows a marked reduction in probability, relative to climatology, of the less active categories and increased probability of the above-average (e.g. ACE index between 120 and 150) categories.

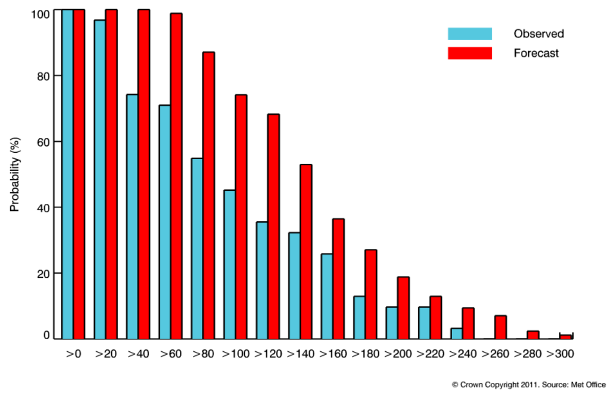
The predicted probability of exceeding the ACE index observed in a selection of past years (June–November) is given below:

- probability of exceeding an ACE index of 164 (2010) is approximately 36%; the climatological chance is approximately 25%.
- probability of exceeding an ACE index of 53 (2009) is approximately 100%; the climatological chance is approximately 74%.
- probability of exceeding an ACE index of 242 (2005) is approximately 9%; the climatological chance is less than 1%.

Accumulated Cyclone Energy (ACE) Index
June–November 2011



PDF: Probability that the ACE index will lie within given ranges



CDF: Probability that the ACE index will exceed a given threshold

Climate and forecast probabilities that the ACE index will exceed a given threshold. Note: probabilities are given to one decimal place to help preserve a smooth distribution. Accuracy to one decimal place is not implied.

ACE Index	Climate probability 1980–2010	Forecast probability 2011
> 0	100.0	100.0
> 10	100.0	100.0
> 20	96.8	100.0
> 30	90.3	100.0
> 40	74.2	100.0
> 50	74.2	100.0
> 60	71.0	98.8
> 70	64.5	92.9
> 80	54.8	87.1
> 90	51.6	82.4
> 100	45.2	74.1
> 110	38.7	74.1
> 120	35.5	68.2
> 130	35.5	62.4
> 140	32.3	52.9
> 150	25.8	41.2
> 160	25.8	36.5
> 170	16.1	31.8
> 180	12.9	27.1
> 190	9.7	22.4
> 200	9.7	18.8
> 210	9.7	15.3
> 220	9.7	12.9
> 230	3.2	11.8
> 240	3.2	9.4
> 250	0.0	9.4
> 260	0.0	7.1
> 270	0.0	4.7
> 280	0.0	2.4
> 290	0.0	2.4
> 300	0.0	1.2

Sea Surface Temperature: Monitoring and Prediction

El Niño–Southern Oscillation (ENSO)

The El Niño-Southern Oscillation is a large-scale, natural fluctuation of the ocean-atmosphere system centred in the tropical Pacific region. Warm (El Niño) and cold (La Niña) phases recur every few years and represent opposite extremes in the ENSO cycle. An ENSO-neutral phase refers to those periods when neither El Niño nor La Niña is present. These periods often coincide with the transition between El Niño and La Niña events.

The impact of ENSO can extend to near-global dimensions via teleconnections. In the North Atlantic, tropical storm activity tends to be reduced during El Niño events and enhanced during La Niña events. A broad range of activity may occur in neutral years (e.g. 28 storms in 2005, 4 storms in 1983).

In this document references to El Niño and La Niña relate only to sea-surface-temperature anomalies in the tropical Pacific Niño3.4 region (120°–170°W, 5°N–5°S). Our references to El Niño, neutral and La Niña conditions generally correspond to sea-surface-temperature (SST) anomalies >0.5°C, between -0.5 and +0.5°C, and <-0.5°C, respectively.

CURRENT CONDITIONS:
15 May 2011
Source: OSTIA

SSTs in the tropical Pacific Niño3.4 region (not shown) are near normal, indicating neutral conditions.

FORECAST:

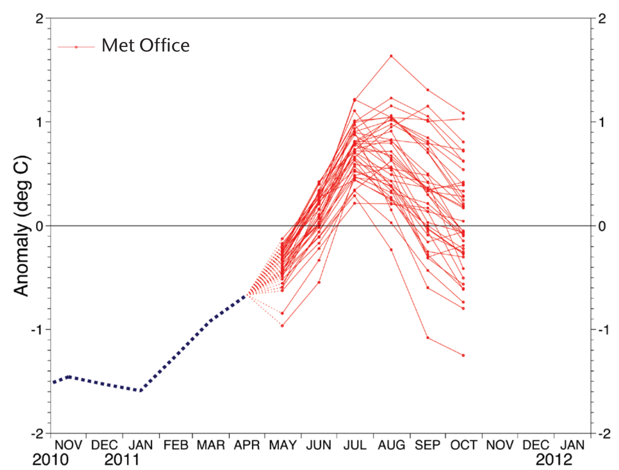
The Met Office and ECMWF seasonal forecasting systems predict recovery from below-normal SSTs in the Niño3.4 region, but at different rates.

- The Met Office system predicts rapid transition to near- to above-normal SSTs by the peak of the hurricane season (August to October).
- The ECMWF system predicts neutral conditions as most likely by the peak of the hurricane season.

Overall the uncertainty towards the end of the forecast period is large, with all of La Niña, neutral or El Niño conditions potentially possible. This reflects the relatively low predictability of the ENSO evolution from this time of year. Given such a range of conditions, the influence of ENSO in the North Atlantic, which is a key driver of tropical storm activity, is uncertain.

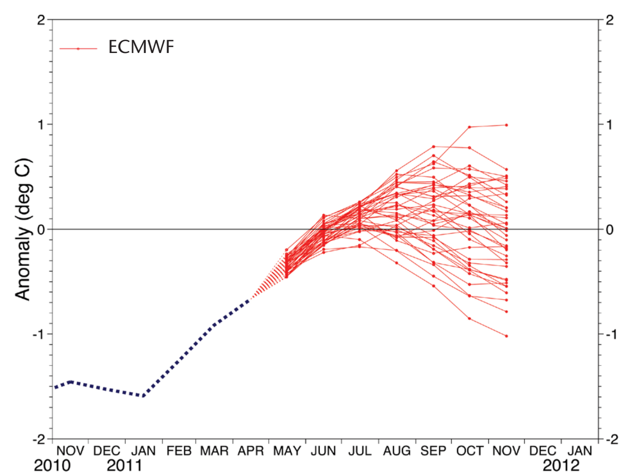
Met Office predicted Niño3.4 SST anomalies from 1 May 2011. Anomalies are relative to 1971–2000.

Source: ECMWF



ECMWF predicted Niño3.4 SST anomalies from 1 May 2011. Anomalies are relative to 1971–2000.

Source: ECMWF



North Atlantic Main Development Region (MDR)

Tropical cyclones require local SSTs to be greater than around 26.5°C for development and intensification. Prolonged periods of above-normal SSTs are typical of active hurricane seasons.

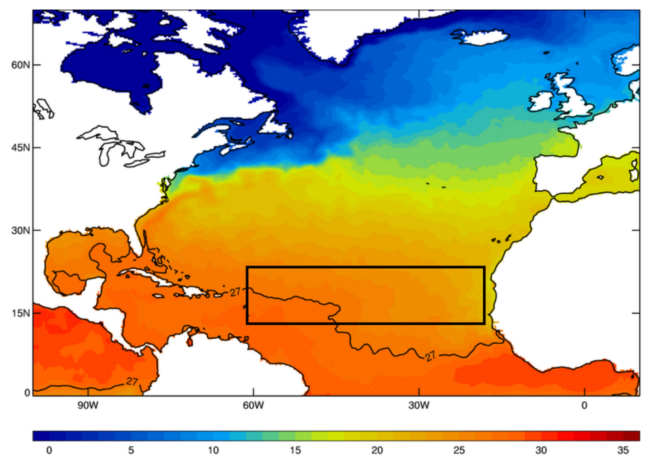
CURRENT CONDITIONS:
10–17 May 2011

SSTs in the southern Gulf of Mexico, Caribbean Sea and the southwest region of the tropical North Atlantic MDR (shown boxed in figure) are currently above the 26.5°C threshold required for tropical storm development and intensification.

Right: The 27°C isotherm (labelled contour on the map) shows regions favourable for tropical cyclone development and intensification.

Observed SST (°C)
10–17 May 2011

Source: OSTIA

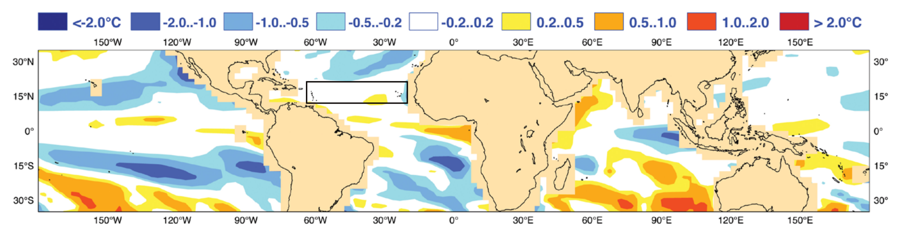


SST ANOMALY FORECAST:
August-October 2011

The Met Office and ECMWF seasonal forecasting systems signal near- to slightly above-normal SSTs in the North Atlantic MDR (shown boxed in figures), Caribbean Sea and Gulf of Mexico during the peak of the hurricane season from August to October 2011.

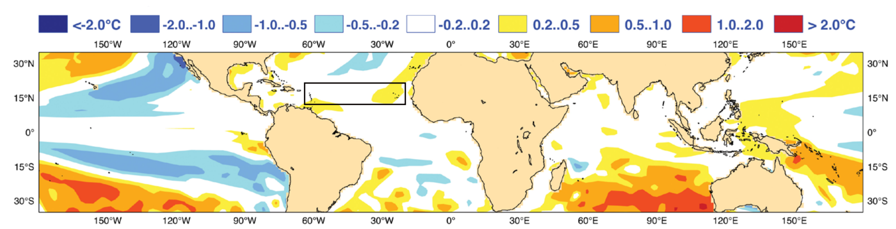
Met Office predicted SST anomaly for August–October 2011 (ensemble mean). Forecast issued 1 May 2011. Anomalies are relative to 1971–2000.

Source: ECMWF



ECMWF predicted SST anomaly for August–October 2011 (ensemble mean). Forecast issued 1 May 2011. Anomalies are relative to 1971–2000.

Source: ECMWF



Vertical Wind Shear

Vertical wind shear is a measure of the variation of the horizontal wind with height. In this instance the shear is measured between the 200 hPa and 850 hPa pressure surfaces. Low values of vertical wind shear, typically below 10ms^{-1}, are considered favourable for tropical storm development and intensification. Above this threshold, wind shear causes the displacement of moisture away from the low-level circulation inhibiting tropical cyclone genesis and intensification.

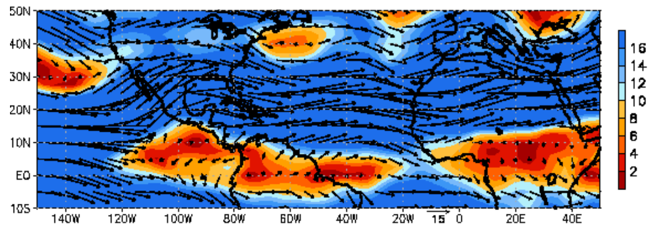
Seasonal forecasts of wind shear of relevance to cyclogenesis are not derived presently from global dynamical forecasting models. Wind shear is known to be connected to the phase of ENSO, but is also influenced by other local factors.

CURRENT CONDITIONS:
5–15 May 2011

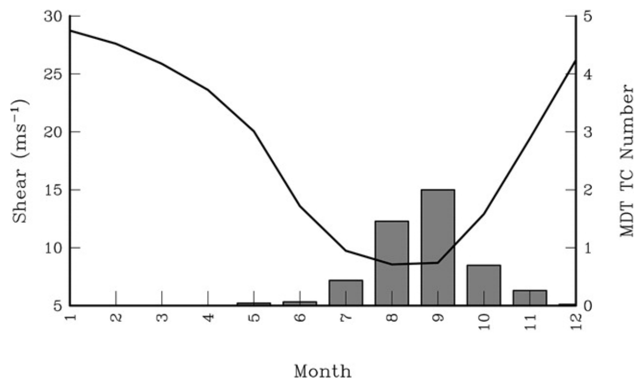
The average magnitude of the vertical wind shear (top figure) is currently too great for tropical storm development. These conditions are typical of those at this time of the year. The mean vertical wind shear over the MDR, which is highest during January, decreases through the boreal spring and summer to a minimum in August and September before increasing again during late autumn (bottom figure).

11-day average vertical wind sheer magnitude (ms^{-1}) 5–15 May 2011

Source: CPC/NCEP



Yellow and red colours indicate values favourable for tropical storm development and intensification; blue colours indicate unfavourable conditions.



Monthly averaged vertical wind shear (ms^{-1}; thick line) versus tropical cyclone formation (shaded bars) within the MDR, 1958–2003.

Source: Aiyyer and Thorncroft (2006).

Forecasts from Other Centres

Long-range seasonal forecasts of tropical storm activity for June–November 2011 have been issued by Colorado State University (CSU), Tropical Storm Risk (TSR) and the National Oceanic and Atmospheric Administration (NOAA). These predictions are based on statistical or empirical forecasting methods and are summarised in the table below.

		Statistical forecasts		
Centre	**Issued**	**Tropical storms**	**Hurricanes**	**ACE index**
CSU	6 April 2011	16	9	160
TSR	5 April 2011	14.2 (±3.9)	7.5 (±2.8)	124 (±56)
NOAA	19 May 2011	12–18	6–10	98–186

The statistical seasonal forecasts, issued in April and May 2011, predict, as most likely, above-average numbers of tropical storms and ACE index during the 2011 Atlantic hurricane season, relative to the 1980–2010 climatology (12 tropical storms and an ACE index of 105).

The next seasonal forecasts are due to be released by TSR on 24 May 2011 and CSU on 1 June 2011.

Future Forecasts

The next Met Office seasonal tropical storm outlook will be issued in June 2011.

Contact Point

For further information please contact matt.huddleston@metoffice.gov.uk.

Forecast Methodology

The forecast is produced using the seasonal forecast systems of the Met Office and the European Centre for Medium Range Weather Forecasts (ECMWF). The procedure involves tracking of storms in the forecasts of both systems, forecast calibration to improve consistency with past observed storm numbers, and combining of the resultant output of both systems into a single 'multi-model' prediction. More details on these stages of the procedure are given below.

Dynamical forecasting systems

The seasonal forecast is derived using information from two global dynamical seasonal prediction systems: the Met Office GloSea4 system (Arribas et al, 2010) and ECMWF system 3 (Anderson et al, 2007; Molteni et al, 2007). These systems are similar to the computer models used for short-range forecasting. An important difference is that they include a fully interactive ocean component and as such are referred to as coupled ocean-atmosphere systems. Inclusion of the interactive ocean is important to capture sea-surface-temperature evolution that influences tropical storm development.

The models therefore represent the physical processes that control tropical storm frequency, including non-linear interactions between such processes. This is an advantage relative to statistical or empirical methods which rely on past relationships between storm numbers and preceding observed conditions (e.g. preseason SST patterns).

The models are initialised with analyses of the global oceans, land and atmosphere, which provides the model with a description of the current climate state, an important factor in obtaining realistic predictions. Uncertainties in the forecast arise from our imperfect knowledge of the current climate state and from imperfect representation of physical processes by the models. To quantify these intrinsic uncertainties, many individual predictions are made for each forecast, each from slightly different initial conditions and with stochastic variations to model physics parameters. The resulting set of predictions is referred to as an 'ensemble', and each prediction as an 'ensemble member'.

The ensemble is then used to generate probability forecasts: e.g. the forecast probability for more than say 15 tropical storms is the proportion of ensemble members that predict more than 15. A single best estimate forecast is also obtained by averaging over all ensemble members. The forecast probabilities are derived from ensemble members pooled over both the Met Office and ECMWF systems. This so called 'multi-model' approach has been demonstrated to give superior skill, on average, than either of the individual systems (Vitart et al 2007).

Tracking tropical storms

Dynamical models used for seasonal forecasts have a spatial resolution that is too coarse to describe detailed features of individual tropical storms and their intensity. However, models can represent large-scale features which are indicative of tropical storms; for example, low central pressure and high relative vorticity. These features can be tracked and counted to arrive at a total number of storms for the season.

The tropical storm tracking methods used for the Met Office and ECMWF forecasts are different. In the Met Office system, model storms are identified by relative vorticity maxima at 850hPa in daily instantaneous fields, and sequences of maxima sufficiently close together on successive days are identified as storm tracks. Extra-tropical systems that may be detected in the analysis are excluded by only retaining storms with genesis south of 30°N.

In the ECMWF system additional constraints on identification of storms are used. For example, only storms that develop a warm temperature anomaly above the centre of the vortex (known as a warm core) are considered—for further details see Vitart et al (1997, 2001, 2003).

Calculating the ACE index

In each ensemble, the accumulated cyclone energy (ACE) index for each model storm is combined to arrive at the seasonal total ACE index. The ACE index is calculated as the square of the maximum wind speed throughout the storms lifetime.

Calibration

Because the dynamical model grid does not fully resolve relatively small features such as tropical storms, a calibration procedure is applied which adjusts the number of detected tropical storms and the ACE index. The calibration factor is derived by comparing the number of predicted tropical storms and ACE index with observations over a series of retrospective forecasts (also known as hindcasts). The retrospective forecasts are independent for each model and available over different historical periods: for the Met Office system the period 1996–2009 is used; for the ECMWF system the period 1987–2009 is used.

The multi-model ensemble

The Met Office system has a 42-member forecast ensemble and the ECMWF system a 41-member forecast ensemble. The number of tropical storms in each ensemble member of each system is determined and these are combined to produce forecast products based on an 83-member multi-model ensemble. The mean and the standard deviation of the combined ensemble provide the forecast best-estimate and the two-standard-deviation range (calculated as ± 1 standard deviation about the ensemble mean). These values are then compared to the 1980–2010 long-term average over the same 6-month period of the forecast. (NB. As the forecast ensemble does not necessarily follow a normal distribution, the ± 1 standard deviation range does not provide a 68% confidence interval).

Forecast skill

Forecast skill of the Met Office-ECMWF multi-model is presented (in the body of the report) for ensemble-mean-predicted numbers of tropical storms and ACE index for the common period 1996–2009. The calibrated number of model storms and ACE index for each year is determined independently for each model and then combined with equal weighting to create the multi-model hindcast ensemble. For both systems the number of ensemble members is smaller for the hindcasts than the real-time forecasts: Met Office hindcast ensembles have 12 members and ECMWF hindcasts have 11 members, resulting in a multi-model hindcast of 23 members per year. Skill is assessed using Pearson linear correlation, which measures the strength of the relationship between forecasts and observations over the period.

Probability and cumulative distribution functions

Probability forecast information is derived from the combined 83-member multi-model ensemble. The probability distribution function (PDF) provides the forecast probability that the number of tropical storms or ACE index will be within discrete ranges. The cumulative distribution function (CDF) provides forecast probabilities for exceeding a given number of storms or ACE index. The empirical distributions have not been smoothed or fitted to a functional form. Forecast probabilities are compared to observations over the period 1980–2010.

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Glossary and Definitions

ACE (ACCUMULATED CYCLONE ENERGY) INDEX

A measure of the collective strength and duration of tropical cyclones during the season, defined by NOAA as the sum of the squares of the 6-hourly maximum wind speed for all named systems whilst they are at least tropical storm strength (winds >39 mph). Units of ACE index are 10^4 $knots^2$. See also http://www.cpc.noaa.gov/products/outlooks/background_information.shtml

CPC

U.S. Climate Prediction Center.
See http://www.cpc.noaa.gov/products/hurricane/

ECMWF

The European Centre for Medium Range Weather Forecasts

EL NIÑO

The warm phase of ENSO associated with a warming of the central and eastern equatorial Pacific Ocean. El Niño events occur irregularly every 2–7 years and typically last between 12 and 18 months. During El Niño events, upper-level westerly winds generally increase across the tropical North Atlantic resulting in above-average vertical wind shear in the MDR. These conditions are unfavourable for tropical cyclone development and often lead to reduced tropical cyclone activity during the hurricane season. See also http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensofaq.shtml

ENSO (EL NIÑO-SOUTHERN OSCILLATION)

A large-scale, natural fluctuation of the ocean-atmosphere system centred in the tropical Pacific region; warm (El Niño) and cold (La Niña) phases recur every few years. Through teleconnections to higher latitudes, ENSO impacts can extend to near-global dimensions.

EUROSIP (EUROPEAN SEASONAL TO INTER-ANNUAL PREDICTION)

Multi-model seasonal prediction system comprising the dynamical seasonal prediction systems of ECMWF, Met Office (GloSea4) and Météo-France. The combined forecast ensemble size for the multi-model is 124.

GLOSEA4 (GLOBAL SEASONAL FORECASTING SYSTEM VERSION 4)

The Met Office seasonal forecasting system used operationally since September 2009. Forecasts are generated monthly with a 42-member ensemble.

HURDAT (HURRICANE DATABASE)

The observed record of all tropical cyclones in the North Atlantic basin maintained by NOAA.
See http://www.aoml.noaa.gov/hrd/hurdat

HURRICANE

A tropical cyclone with maximum sustained wind speeds of 74 mph or greater (categories 1–5 on the Saffir-Simpson hurricane wind scale).

IRI

International Research Institute for Climate and Society

LA NIÑA

The cold phase of ENSO leading to extensive cooling of the central and eastern Pacific, typically lasting between 12 and 18 months. During La Niña events, upper-level westerly winds are reduced across the tropical North Atlantic, leading to an extended area of below-normal vertical wind shear across the MDR. This creates favourable conditions for tropical cyclone development and intensification often leading to enhanced tropical cyclone activity and landfall risk.

MDR (MAIN DEVELOPMENT REGION)

A region in the tropical North Atlantic between Africa and the Caribbean Sea between 10°–20°N, 20°–60°W where most major hurricanes (winds ≥111 mph) develop.

MAJOR HURRICANE

A tropical cyclone with maximum sustained wind speeds of 111 mph or greater (categories 3–5 on the Saffir-Simpson hurricane wind scale).

NCEP

U.S. National Centers for Environmental Prediction

OSTIA

The Met Office Operational SST and Sea Ice Analysis

NOAA

U.S. National Oceanic and Atmospheric Administration

SAFFIR-SIMPSON HURRICANE WIND SCALE

A scale ranging from 1 to 5 (one being the weakest category and 5 the greatest) used to categorise hurricanes based on their maximum sustained surface wind speed. Category 1 hurricanes have maximum sustained wind speeds of at least 74 mph; category 5 hurricanes have winds of at least 155 mph. Details of hurricane damage and impacts for these categories can be found at http://www.nhc.noaa.gov/sshws.shtml

SST

Sea surface temperature

TROPICAL CYCLONE

The generic term for a non-frontal low pressure system that originates over tropical or sub-tropical waters, with organised convection and maximum winds at low levels, circulating either anti-clockwise in the northern hemisphere or clockwise in the southern hemisphere.

TROPICAL STORM

A tropical cyclone with maximum sustained wind speeds between 39 and 73 mph.

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