Met Office

Outlook

Seasonal Tropical Storm Outlook for the North Atlantic

May 2012

Contents

Seasonal Tropical Storm Outlook for the North Atlantic: June–November 2012

Executive Summary

The latest seasonal forecast indicates *near- to below-normal* tropical storm activity in the North Atlantic during June–November 2012:

- The dynamical model prediction is for *10 tropical storms, with a two-standard-deviation range of 7–13*.
- The most likely predicted ACE index is *90, with a two-standard-deviation range of 28–152*.
- Linear correlations between predictions and observations are: 0.39 for tropical storm numbers and 0.36 for ACE index.

The relatively large range around the best-estimate forecast is indicative of uncertainty in the evolution of the El Niño–Southern Oscillation (ENSO), with the Met Office and ECMWF ensemble seasonal forecasting systems predicting as most likely neutral to El Niño conditions by the end of the forecast period.

Sea-surface-temperatures (SSTs) across the tropical North Atlantic are predicted to be near- to below-normal during the peak of the hurricane season (August–October 2012).

The probability of exceeding, in 2012, the observed number of tropical storms recorded during the least and most active past seasons (June–November 1980–2010):

- 1983 (4) is 98.9%.
- 2005 (27) is <1%.

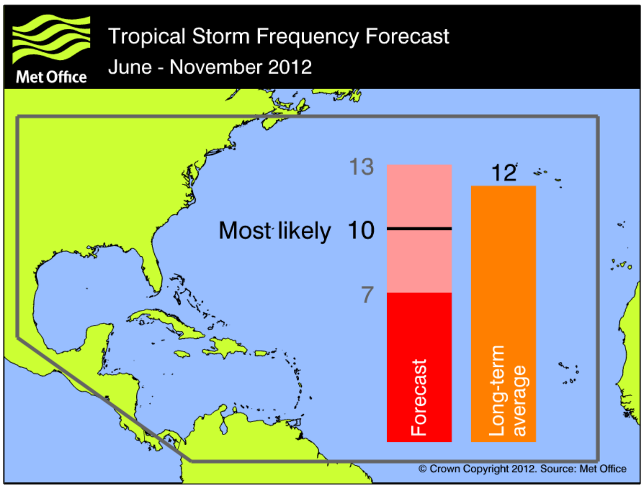
Observed tropical storm activity (June–November) in the last 7 years							
	2005	2006	2007	2008	2009	2010	2011
Tropical storms	27	10	13	16	9	19	19
ACE index	230	79	71	144	53	165	125

Forecast for June–November 2012

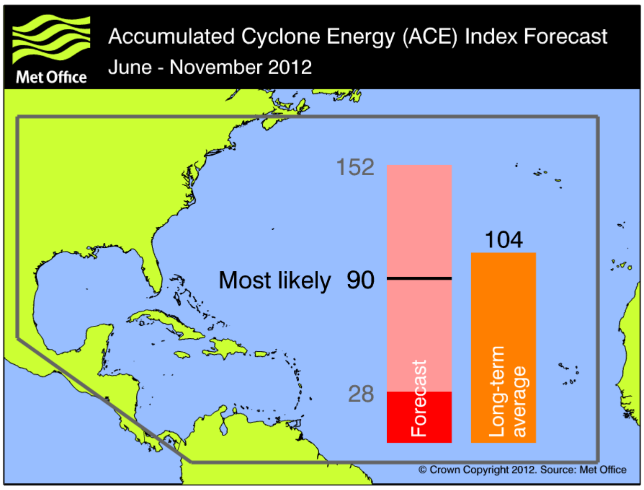
Seasonal tropical storm frequency and ACE index forecasts are based on combined output from the Met Office and ECMWF ensemble seasonal forecasting systems, which together have 93 ensemble members. In this section we present both deterministic and probabilistic forecasts, for total numbers of tropical storms and ACE index during the period. The deterministic forecast consists of a most likely value (based on the ensemble mean) and a predicted range (±1 standard deviation about the ensemble mean). The probabilistic forecast is presented both as a graph of probabilities for discrete ranges of activity and a table showing the probability for exceeding a given threshold. A full description of the forecast methodology is available at the end of this report.

Deterministic Forecast

The most likely number of tropical storms predicted to occur in the North Atlantic basin during June–November 2012 is 10, with a two-standard-deviation range of 7–13. The long-term (1980–2010) average number of tropical storms is 12.



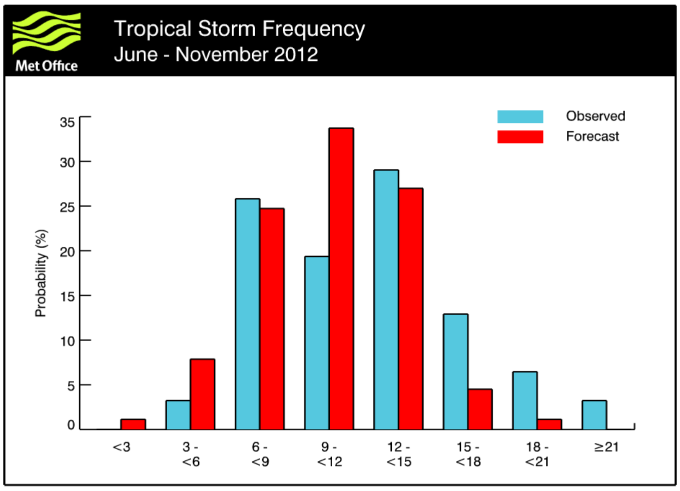
The most likely predicted ACE index is 90, with a two-standard-deviation range of 28–152. The long-term average ACE index is 104.



Probabilistic Forecast

Tropical Storm Frequency

The probability distribution for the number of tropical storms predicted for June–November 2012 shows a distribution similar to climatology, but with reduced probability of very high numbers (e.g. >18 tropical storms).

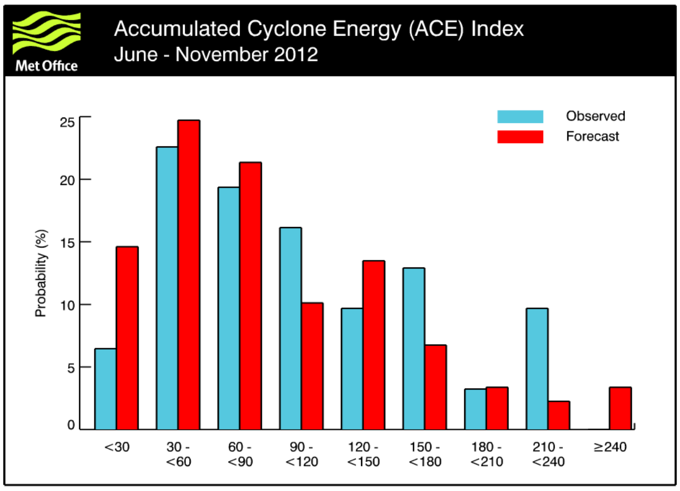


The predicted probability of exceeding a given number of tropical storms is shown in the table on the right. For comparison with recent years, during June–November there were 9 tropical storms in 2009, 19 tropical storms in 2011, and 27 tropical storms in 2005.

Number of tropical storms	Forecast probability 2012	Climate probability 1980–2010
> 3	98.9	100.0
> 4	98.9	96.8
> 5	98.9	96.8
> 6	91.4	87.1
> 7	78.5	80.6
> 8	71.0	71.0
> 9	64.5	67.7
> 10	48.4	64.5
> 11	35.5	51.6
> 12	29.0	38.7
> 13	21.5	29.0
> 14	17.2	22.6
> 15	5.4	12.9
> 16	4.3	9.7
> 17	1.1	9.7
> 18	1.1	9.7
> 19	<1.0	3.2
> 20	<1.0	3.2
> 21	<1.0	3.2
> 22	<1.0	3.2

ACE Index

The forecast probability distribution for ACE index shows a distribution similar to climatology, although a little broader (see figure), likely reflecting the uncertainty in the El Niño–Southern Oscillation (ENSO).



The predicted probability of exceeding a given ACE index is shown in the table on the right. For comparison with recent years, during June–November the ACE index was 53 in 2009, 125 in 2011, and 230 in 2005.

ACE Index	Forecast probability 2012	Climate probability 1980–2010
> 30	84.9	93.5
> 40	79.6	77.4
> 50	69.9	74.2
> 60	60.2	71.0
> 70	50.5	64.5
> 80	44.1	54.8
> 90	39.8	51.6
> 100	36.6	45.2
> 110	31.2	38.7
> 120	28.0	35.5
> 130	26.9	35.5
> 140	20.4	32.3
> 150	15.1	25.8
> 160	11.8	25.8
> 170	10.8	16.1
> 180	8.6	12.9
> 190	6.5	9.7
> 200	6.5	9.7
> 210	5.4	9.7
> 220	3.2	9.7
> 230	3.2	<1.0
> 240	3.2	<1.0

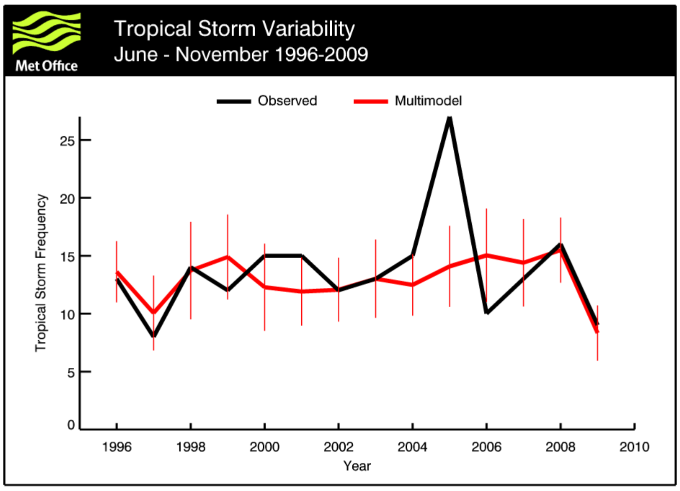
Supporting Information

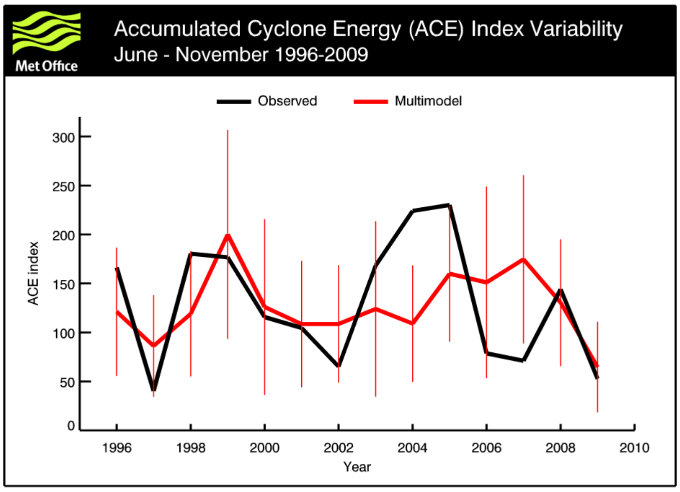
Forecast Skill

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 ensemble size is 27. 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 0.39 for tropical storm numbers and 0.36 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, 1 indicates perfect linear relationship).





Drivers of Predictability: Monitoring and Forecasts

El Niño–Southern Oscillation (ENSO)

ENSO has been found to have an influence on North Atlantic tropical storms. In general, tropical storm activity tends to be reduced during El Niño events and enhanced during La Niña events. A broad range of annual tropical storm activity may occur in neutral years (when neither El Niño or La Niña is present). In this document El Niño, La Niña and neutral conditions refer to the following sea-surface-temperature (SST) anomalies in the tropical Pacific Niño3.4 region (120°–170°W, 5°N–5°S): $>$0.5°C, between -0.5 and +0.5°C, and $<$-0.5°C, respectively.

Current conditions:

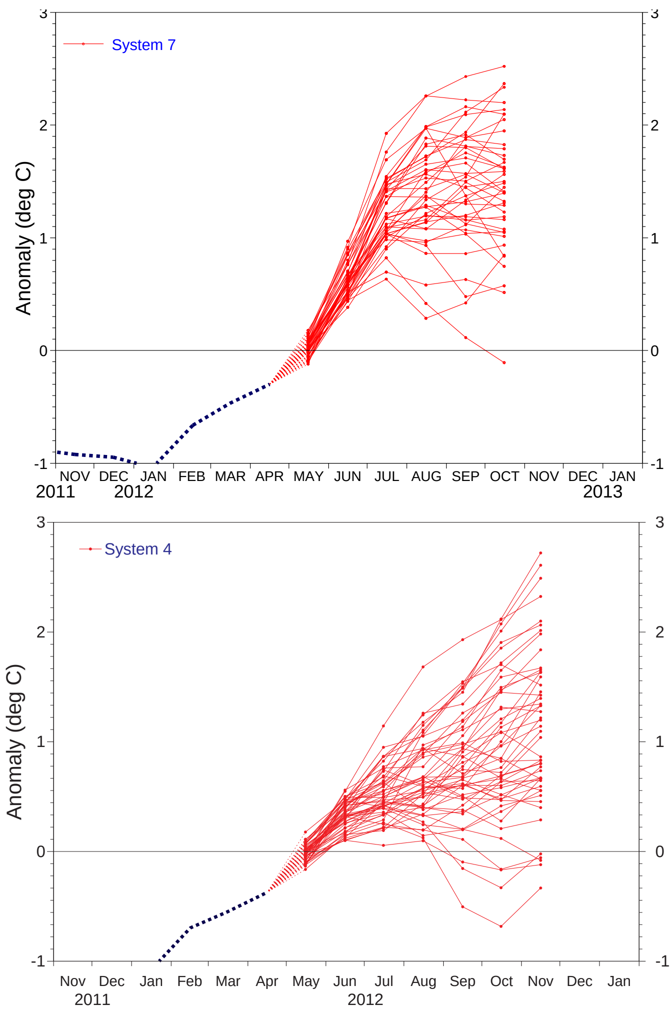
Source: OSTIA

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

Forecast:

The Met Office and ECMWF seasonal forecasting systems (shown in figure) continue to predict a warming of SSTs in the Niño3.4 region. However, there is large uncertainty in the magnitude of the anomalies predicted by the end of the forecast period, with the majority of ensemble members showing monthly mean values of between +0.5°C and +2.0°C (neutral to El Niño conditions). The probability of a return to La Niña conditions is low in the current forecast.

A recent issue of the World Meteorological Organization (WMO) ENSO update, which combines information from several forecast models as well as expert analysis, is available at http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html.



Met Office (top) and ECMWF (bottom) predicted Niño3.4 SST anomalies from 1 May 2012. Source: ECMWF.

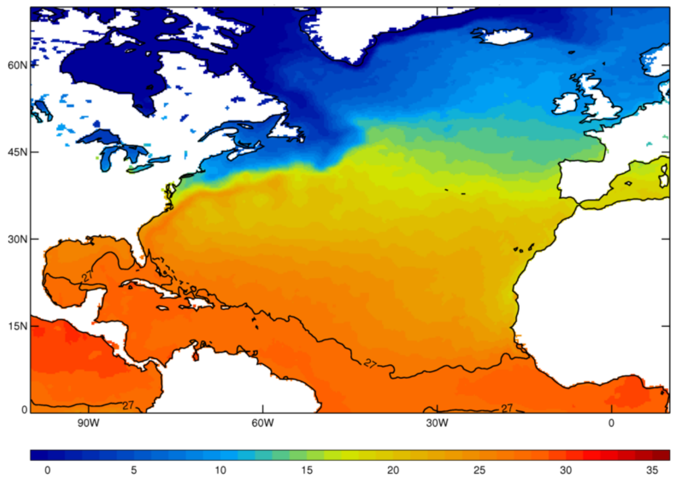
Tropical North Atlantic Sea Surface Temperatures

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

Current conditions:

12–19 May 2012

SSTs in the southern Gulf of Mexico and the Caribbean Sea are currently above the 26.5°C threshold required for tropical storm development. The remainder of the tropical North Atlantic is below the required threshold.

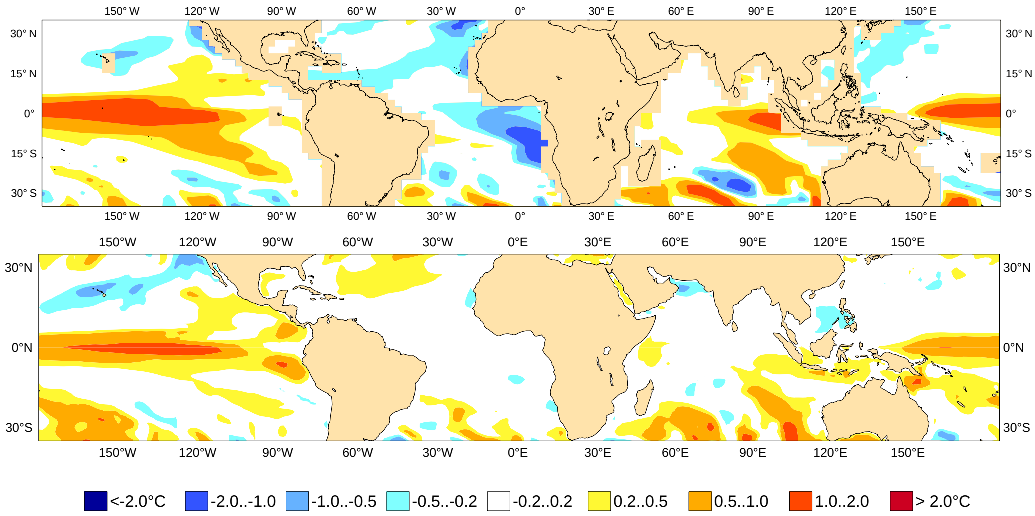


Weekly averaged observed SST (°C). Areas greater than 27°C (labelled contour on the map) show regions favourable for tropical storm development.

Forecast:

August–October 2012

The Met Office and ECMWF seasonal forecasting systems signal near- to below-normal SSTs in the tropical North Atlantic, Caribbean Sea and Gulf of Mexico during the peak of the hurricane season.



Met Office (top) and ECMWF (bottom) predicted SST anomaly (ensemble mean). Forecast issued 1 May 2012. Source: ECMWF

Forecasts from Other Centres

Long-range seasonal forecasts of tropical storm activity for the 2012 Atlantic hurricane season have been issued by Colorado State University (CSU) and Tropical Storm Risk (TSR). These predictions are based on statistical forecasting methods and are summarised in the table below.

Centre	Issued	Tropical storms	Hurricanes	ACE index
CSU	4 April 2012	10	4	70
TSR	12 April 2012	12.5 ($\pm$4.1)	5.6 ($\pm$2.8)	95 ($\pm$55)

The seasonal forecasts, issued in April 2012, predict, as most likely, near- to below-average numbers of tropical storms and ACE index during the 2012 season. The 1980–2010 climatology of June–November is 12 tropical storms and an ACE index of 104. The next seasonal forecasts are due to be released by TSR on 25 May 2012 and CSU on 1 June 2012.

Future Forecasts

The next Met Office Seasonal Tropical Storm Outlook will be issued in June 2012.

Contact Point

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Forecast Methodology

The seasonal tropical storm forecasts are produced using ensemble predictions from the Met Office and the European Centre for Medium Range Weather Forecasts (ECMWF) seasonal forecasting systems. The procedure involves tracking of storms in the forecasts of each system, calibrating the forecast to improve consistency with past observations, and combining of the resultant output into a single 'multi-model' prediction. Below we provide more details on the forecasting systems used and on the stages of the forecast development process.

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., 2011) and ECMWF system 4. These systems use computer models similar to those for short-range weather forecasting. An important difference, however, is that the models used for long-range forecasting include a fully interactive ocean component and are hence referred to as coupled ocean-atmosphere models. The inclusion of an interactive ocean is important, as sea-surface-temperature (SST) evolution influences tropical storm development.

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

Observations of the global oceans, land and atmosphere are used to construct a description of the current climate state. Starting the models from such an initial state is important in obtaining realistic predictions. However, the initial state is not precisely known as observations are sparse, and this leads to uncertainty in the predictions. Uncertainties in the forecast also arise from the imperfect representation of physical processes by models. To quantify these 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: for example, the forecast probability for more than 15 tropical storms is the proportion of ensemble members that have a storm count greater than 15. A single best estimate forecast is also obtained by averaging all ensemble members. Probabilities from individual ensembles can be combined to produce a 'multi-model' ensemble, and this approach applied to the Met Office and ECMWF systems has been demonstrated to give superior skill, on average, to either of the individual systems (Vitart, 2006; 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 thus their intensity and precise track. 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 and the counts adjusted 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, relative vorticity maxima at 850hPa are identified in daily instantaneous fields, and sequences of maxima sufficiently close together on two or more successive days are identified as model storm tracks. Extra-tropical systems that may be detected in the analysis are excluded by only retaining storms with genesis at or below 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); Vitart and Stockdale (2001); Vitart et al. (2003).

Counting hurricane numbers

Hurricanes are detected in the seasonal forecasting systems using the same methodology to track tropical storms, with an additional requirement that a wind speed threshold must also be exceeded. These thresholds are model dependent.

Calculating the ACE index

In each ensemble member, the accumulated cyclone energy (ACE) index for each model storm is combined to arrive at the seasonal total ACE index. The ACE index for a storm is calculated as the square of the maximum wind speed throughout the storm's lifetime. In the Met Office forecasts the wind speeds are determined from 850hPa wind fields; ECMWF forecasts use near-surface (10-metre) wind speeds.

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 model storms and the associated 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 1981–2010 is used.

The multi-model ensemble

The Met Office system has a 42-member forecast ensemble and the ECMWF system a 51-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 a 93-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). (NB. As the forecast ensemble does not necessarily follow a normal distribution, the ± 1 standard deviation range does not provide a 67% 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 hindcast 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 for the real-time forecasts: Met Office hindcast ensembles have 12 members and ECMWF hindcasts have 15 members, resulting in a multi-model hindcast of 27 members per year. Skill is assessed using Pearson linear correlation, which measures the strength of the relationship between ensemble-mean forecasts and observations over the hindcast period.

Probability and cumulative distribution functions

Probability forecast information is derived from the combined 93-member multi-model ensemble. The probability distribution function provides the forecast probability that the number of tropical storms or ACE index will be within discrete ranges. The cumulative distribution function provides forecast probabilities for exceeding a given number of storms or ACE index. The empirical distributions are not smoothed or fitted to a functional form. Forecast probabilities are presented in the context of similar statistics derived from observations over the period 1980–2010.

References

A. Arribas, M. Glover, A. Maidens, K. Peterson, M. Gordon, C. MacLachlan, R. Graham, D. Fereday, J. Camp, A. A. Scaife, P. Xavier, P. McLean, A. Colman, and S. Cusack (2011). The GloSea4 Ensemble Prediction System for Seasonal Forecasting. *Mon. Wea. Rev.*, 139, 1891–1910.

F. Vitart, J. Anderson, and W. Stern (1997). Simulation of interannual variability of tropical storm frequency in an ensemble of GCM integrations. *J. Climate*, 10, 745–760.

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

F. Vitart, D. Anderson, and T. Stockdale (2003). Seasonal forecasting of tropical cyclone landfall over Mozambique. *J. Climate*, 16, 3932–3945.

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

F. Vitart, M. R. Huddleston, M. Deque, 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.

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.

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.

GloSea (Global Seasonal forecasting system)

The Met Office global dynamical seasonal forecasting system.

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).

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.

MDR (Main Development Region)

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

NOAA

National Oceanic and Atmospheric Administration

OSTIA

The Met Office Operational sea surface temperature (SST) and Sea Ice Analysis

Saffir-Simpson hurricane wind scale

A scale ranging from 1 to 5 (one being the weakest category and five the greatest) used to categorise hurricanes based on their maximum sustained surface wind speed. See http://www.nhc.noaa.gov/sshws.shtml.

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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