Met Office tropical storm forecast for the North Atlantic

July to November 2008

Met Office tropical storm forecast for the Atlantic sector, July to November 2008

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Executive Summary

The Met Office coupled ocean-atmosphere seasonal prediction model (known as GloSea) is used to forecast the number of tropical storms (including hurricanes) and Accumulated Cyclone Energy (ACE) index for the Atlantic sector in the period July to November 2008. Recent research has shown that the skill of dynamical systems such as GloSea is challenging or even overtaking that of statistical prediction methods – which to date have formed the basis of most published predictions.

The GloSea model is a physical-dynamical representation of the ocean-atmosphere system, and the number of storms developing in the prediction can be counted to form the basis of the forecast. An ensemble forecasting approach is used in which many parallel predictions are made that sample the forecast uncertainty. This allows a detailed breakdown of the probability of various ranges of storm activity, an advantage that is not readily available from statistical methods.

The forecast is presented in two ways: a 'best estimate' and two-standard-deviation range, and a detailed graphical and tabulated breakdown of the probability of activity ranges and thresholds.

For the 2008 season a best estimate of 15 storms is predicted for the July to November period, with a two-standard-deviation range of 10-20. The detailed breakdown indicates that the upper end of this range is more likely than the lower end. There is an estimated 62.5% probability of more than 12 storms, the number observed in the 2007 (July to November) season, and an estimated 5% probability of an unprecedented number exceeding 25 storms.

The best estimate for the ACE index is 147, with a two-standard-deviation range of 122-172. As for the prediction of storm numbers, the detailed breakdown indicates that probabilities are skewed to the upper end of the range.

A feature of this year's GloSea forecast is the development of a weak-to-moderate El Niño conditions. This likely contributes to the predicted probabilities for a notably inactive season (less than 7 storms) remaining near the climatological chance, despite the general probability shift towards an active season. The dynamical prediction models of some other international centres also predict an El Niño-type development, and this outcome certainly cannot be ruled out. However, international consensus is that near-neutral ENSO (El Niño Southern Oscillation) conditions are most likely to persist through the Atlantic tropical storm season. Development of an El Niño – which may act to suppress Atlantic tropical storm activity – is considered to be a relatively small probability.

1. Introduction

The prediction tool used for this forecast is the Met Office Global Seasonal forecasting system known as GloSea. GloSea is a dynamical numerical model of the climate system with full interactive coupling between the ocean and atmosphere. The number of tropical storms developing in the GloSea seasonal predictions can be counted, and this forms the basis of the forecast. Importantly, GloSea is skilful in predicting the evolution of large-scale ocean-atmosphere processes and interactions that drive the degree of tropical storm activity, and this gives rise to skilful forecasts of tropical storm numbers. Use of dynamical prediction systems represents a new departure in 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 storm numbers and preceding observed conditions (e.g. pre-season sea surface temperature (SST) patterns).

Recent research has shown that, for predictions of tropical storm frequency, the skill of dynamical systems such as GloSea is now challenging or even overtaking that of some well-known statistical methods (Vitart, 2006: Vitart et al., 2007). In particular, GloSea successfully predicted the change from the exceptionally active season of 2005 to the near-normal activity of the 2006 season. This marked difference between seasons was missed by a number of statistical prediction methods. Last year the Met Office's first publicly issued forecast was for 10 storms in the July to November period, with a 70% probability range of 7-13; in the event, 12 storms were observed to occur.

2. Method outline

The GloSea seasonal prediction model is initialised with an analysis of the global oceans, land and atmosphere (see Appendix A for more details). The analysis provides the model with a description of the current climate state, an important factor in obtaining realistic predictions. The forecast presented here is derived from a GloSea prediction initialised on 1st June 2008, and run to 6 months ahead – allowing prediction of the number of storms occurring in the July to November period. The starting conditions are varied slightly to make 41 individual predictions. The 41 predictions are collectively called an 'ensemble' and each individual prediction is called an ensemble 'member'. The frequency of tropical storms in each of the 41 ensemble members is processed to create a probability distribution for the expected number of storms. In addition, the average number of storms over all ensemble members (the ensemble mean) is derived to provide a single 'best estimate' forecast that is the basis of our public forecast. The 'best estimate' is sometimes an oversimplification that does not take full account of the forecast uncertainties addressed by probability forecasts such as those provided in this report.

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 storms. The calibration factor is derived by comparing the number of predicted storms with the number of observed storms over a series of retrospective forecasts. The calibration method has been improved since last year's forecast.

Probabilities that the number of storms will be within ranges or 'categories' (e.g. 10 to 12 storms) can be derived by counting the proportion of the 41 ensemble members that predict the number of storms to fall in that range. Probabilities that the number of storms will exceed a threshold (e.g. the forecast probability for more than 12 storms) can be derived in a similar way.

An important index of seasonal tropical storm activity is the Accumulated Cyclone Energy (ACE) index, which is a measure of the collective intensity and duration of tropical storms during the season (Bell et al., 2000). Forecasts of ACE index are also presented here in addition to forecasts of tropical storm numbers. The forecasts of ACE index are derived using model-predicted wind speeds, and include a calibration procedure similar to that applied for the forecasts of storm numbers (based on comparing predicted and observed ACE index values over a retrospective forecast period). Probability forecasts for categories of ACE index are presented in a similar way to the forecasts for storm numbers.

In last year's report, predicted probabilities for the storm-number categories were based on a blend of the ensemble forecast probabilities and observed climatological probabilities. This blend results in a conservative estimate of the differences between the probability distribution for the predicted year and the climatological probability distribution. This year the forecast is based on the forecast ensemble probabilities alone. The ensemble probabilities show the predicted skews (relative to the climate distribution) more clearly than the blended probabilities. However, because the estimated probabilities are no longer conservative, and because the sample of forecasts is still too small to perform a satisfactory evaluation of any forecast bias in the probabilities, the precise probability values should be treated with caution.

Because of changes in method from that used in last year's forecast, re-forecasts for the 2005, 2006 and 2007 seasons, made with the revisions mentioned above, are provided for comparison with the 2008 forecast in Appendix B.

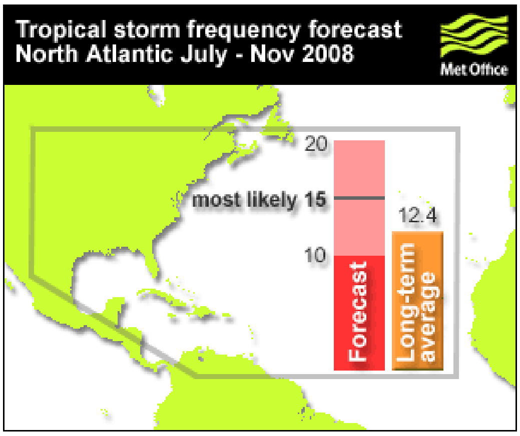

Figure 1: Met Office publicly issued tropical storm forecast for the North Atlantic sector, July-November 2008

3. The public forecast issued 18th June 2008

The public forecast is based on the ensemble-mean prediction, with a range defined by plus and minus one standard deviation of the 41 ensemble members about the ensemble mean (referred to hereafter as the two-standard-deviation range). This yields 15 tropical storms as the 'best estimate' for the number occurring in the North Atlantic during the July to November 2008 period, with a range of 10 to 20. Fifteen storms represents above normal activity relative to the 1990-2005 long-term average of 12.4 (Fig. 1).

4. Forecast detail

4.1 Tropical storm numbers

Figures 2a and b and Table 1 provide probability forecast information, derived from the 41-member ensemble, that provides additional detail on the ensemble mean forecast and two-standard-deviation range (Fig. 1). Figure 2a provides the forecast probability (red) that the number of storms will be within given ranges, while Figure 2b and Table 1 provide forecast probabilities for exceeding a given number of storms. The equivalent observed frequencies, based on the 1987-2007 period, are also shown and are taken from the NOAA HURDAT dataset (Jarvinen et al., 1984). The forecast and observed probabilities are based directly on counts of storms and the distribution is not smoothed or fitted to a functional form. The main features of the forecast probabilities are summarised below.

- The forecast probability distribution (red) is shifted to the more active categories relative to the climate distribution (green). The 19-21 category is the mode of the forecast distribution, whereas the 10-12 category is the mode in climatology (the mode is the category with the highest probability).
- The 13-15 category, which includes the ensemble mean (15), is the second most likely of the categories defined (Fig. 2). The fact that the mode of the forecast distribution does not include the ensemble mean reflects the multi-modal nature of the forecast distribution. The forecast distribution indicates that the upper end of the 10-20 range is more likely than the lower end or, indeed, the middle of the range.
- The skew in the forecast distribution to the active categories is compensated by reduced probability (relative to climatology) of the 7-9, 10-12 and 13-15 categories. However, the probability of a very inactive season (<7) is not reduced, and has a forecast probability that is similar to that of climatology.
- The climatological mode (10-12) is the category most diminished in the forecast distribution relative to climatology. Forecast probabilities for categories more active (e.g. 16-18, 19-21) and less active (e.g. 7-9) than the climatological mode are larger than the forecast probability for the climatological mode itself.
- The above two points suggest that there are conflicting large-scale influences on storm numbers that act to reduce the probability of a 'normal' season, increase the chance of an active season and to retain the usual (climatological) probability of an inactive season. Possible reasons for this distribution of probabilities are discussed in section 5.
- The probability of more storms than observed last year (12) is 62.5%, compared to a climate chance of 33.3% (Fig. 2a, Table 1).
- The forecast probability of more than 25 storms is 5% (Fig. 2b, Table 1).

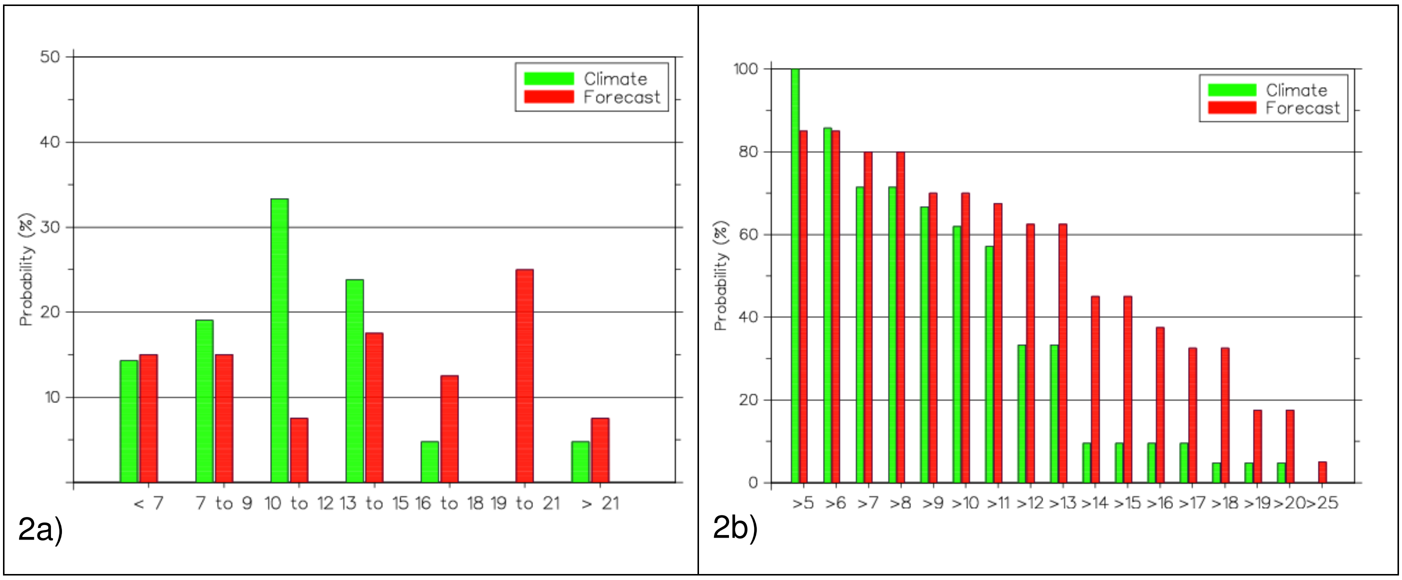

Figure 2: a) Probability that the number of Atlantic sector tropical storms, in the July to November 2008 period, will lie within given ranges. Red = forecast probabilities for 2008; green = climatological frequencies (1987-2007) derived from the NOAA HURDAT dataset. b) as a), but showing the probability that the number of Atlantic sector tropical storms, in the July to November 2008 period, will exceed a given number. Note: the forecast and climatological probabilities appear 'stepped' because they are based directly on storm counts, the distribution has not been smoothed or fitted to a functional form.

Number of storms	Climate Probability 1987-2007	Forecast Probability 2008
>6	85.7	85.0
>7	71.4	80.0
>8	71.4	80.0
>9	66.7	77.5
>10	61.9	70.0
>11	57.1	70.0
>12	33.3	62.5
>13	33.3	62.5
>14	9.5	45.0
>15	9.5	45.0
>16	9.5	37.5
>17	9.5	32.5
>18	4.8	32.5
>19	4.8	17.5
>20	4.8	17.5
>25	0.0	5.0

Table 1: The climate and forecast probabilities that the number of Atlantic sector 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

4.2 Accumulated Cyclone Energy (ACE) index

For the July to November 2008 period the predicted ensemble-mean ACE index is 147 (units are 10^4 knots^2) with a two-standard-deviation range of 122-172, which represents above average activity relative to the 1990-2005 long-term average of 131. The probability distributions (Figs. 3a and b) show similar skew characteristics to those of the storm number probabilities (Figs. 2a and b), with enhanced probability for an active season (particularly the 160 to 189 category), reduced probability for the middle range (70-99, 100-129, 130-159), and near climatological probabilities for a particularly inactive season (less than 70). Thus, as for storm numbers, the probabilities for ACE index are skewed to the upper end of the two-standard-deviation range. The forecast probability that the ACE index for the July to November 2008 period will be greater than last year's full season value of 71 is 77.5% compared with a climatological chance of 66.7% (Fig. 3b, Table 2).

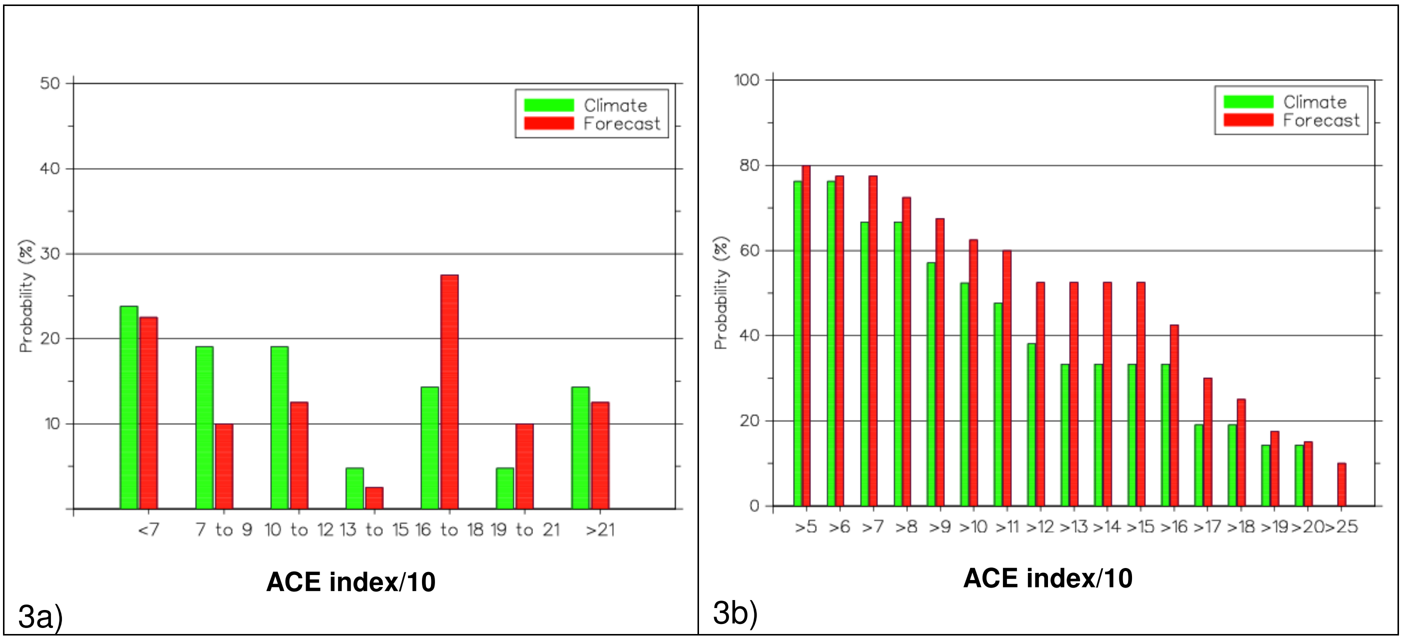

Figure 3: a) Probability that the Accumulated Cyclone Energy (ACE) index, in the July to November 2008 period, will lie within given ranges. Red = forecast probabilities for 2008; green = climatological frequencies derived from observations, 1987–2007. ACE index values are taken from the NOAA HURDAT dataset. For presentation purposes the ACE index values have been divided by 10, and the upper value of the ACE index range is displayed truncated (e.g. 7 to 9 refers to an ACE range of 70 to 99, strictly 70 ≤ ACE index < 100). b) As a) but showing the probability that the ACE index for the July to November 2008 period will exceed a given value.

ACE index	Climate Probability 1987-2007	Forecast Probability 2008
>60	76.2	77.5
>70	66.7	77.5
>80	66.7	72.5
>90	57.1	67.5
>100	52.4	62.5
>110	47.6	60.0
>120	38.1	52.5
>130	33.3	52.5
>140	33.3	52.5
>150	33.3	52.5
>160	33.3	42.5
>170	19.0	30.0
>180	19.0	25.0
>190	14.2	17.5
>200	14.3	15.0
>250	0.0	10.0

Table 2: The climate and forecast probabilities that the ACE index for July to November 2008 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.

5. Sea surface temperature predictions for the 2008 season

A large proportion of the inter-annual variability in North Atlantic tropical storm activity is linked to sea-surface temperature (SST) variability in the tropical Pacific Ocean (associated with the El Niño Southern Oscillation – ENSO) and in the tropical North Atlantic. The success of the dynamical model forecasts is rooted in good prediction skill for SST in these regions and also in an ability to correctly translate predicted SST variability into variability of tropical storm frequency – through representation of ENSO impacts on Atlantic vertical wind shear and through local SST impacts (Vitart et al., 2007).

The GloSea ensemble-mean SST forecast for the August-September-October period, encompassing the climatological peak of the tropical storm season, is provided in Fig. 4. The forecast indicates above-normal SST in the tropical Pacific – suggesting development of El Niño-type conditions. Near or above-normal SST is predicted in the so-called Main Development Region for tropical storms in the tropical North Atlantic (10˚N to 20˚N; 20˚W to 60˚W), which represents a warming relative to the negative anomalies observed in the western basin in June. El Niño conditions tend to suppress North Atlantic tropical storm activity, while above-normal SST in the tropical North Atlantic tends to enhance activity. The predicted SST anomalies in these two regions therefore have conflicting influences on predicted tropical storm numbers, and this is consistent with the forecast probability distributions (Figs 2a and b) which indicate reduced probability (relative to climatology) of a 'normal' season, enhanced probability of an active season, and little reduction in the probability of an inactive season.

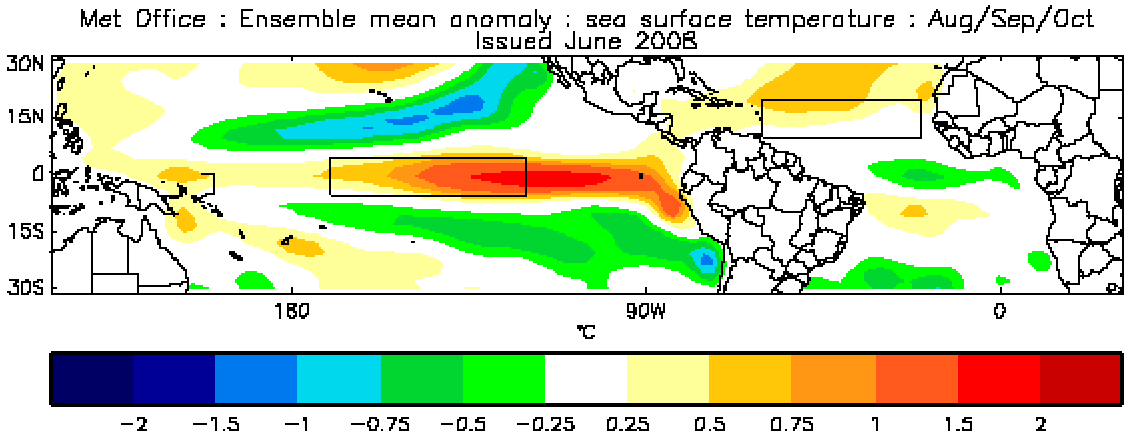

Figure 4: Ensemble-mean sea-surface temperature anomalies for August-September-October predicted from June 2008. Anomalies are expressed relative to the 1987-2001 period. Note positive anomalies are predicted in the eastern tropical Pacific (the boxed area shown is the Niño3.4 region (5˚S to 5˚N; 120˚W to 170˚W) often used to monitor El Niño/La Niña development), and neutral or warm anomalies in the Main Development Region (shown boxed – 10˚N to 20˚N; 20˚W to 60˚W) in the tropical North Atlantic.

It should be emphasised that there is considerable uncertainty associated with the evolution of SST in the tropical Pacific over the July to November period. For the first part of June 2008, SST anomalies reflected the slow decay of the La Niña conditions that have prevailed since summer 2007; SST anomalies were still negative in the central Pacific but positive in the eastern Pacific. The GloSea model predicts a rapid warming of SST in the Niño3.4 region, with the ensemble members centred around an anomaly of about 1.0˚C by September (Fig. 5). However, the amplitude of the predicted anomalies is large relative to the predictions from some other models, and must be viewed with caution.

The GloSea forecast may be compared with a range of other dynamical and statistical predictions of tropical Pacific SST in Fig. 6, which is taken from the website of the International Research Institute for Climate and Society (IRI). Figure 6 shows that a number of other (though not all) dynamical models also favour development of positive SST anomalies – though with less amplitude than predicted by GloSea. In contrast most statistical methods favour continuation of the present near-neutral or negative SST anomalies.

An international consensus, coordinated by the World Meteorological Organisation (WMO) – which includes interpretation of dynamical output from many prediction models – currently favours ENSO-neutral conditions to be in place for the next few months. Near-neutral conditions are also considered the most likely outcome for the remainder of the year, albeit with a small chance of El Niño conditions developing.

As several coupled ocean-atmosphere systems in addition to GloSea also indicate development of a weak to moderate El Niño, this potential outcome – which would contribute to suppression of tropical storm activity for the 2008 season – certainly cannot be ruled out.

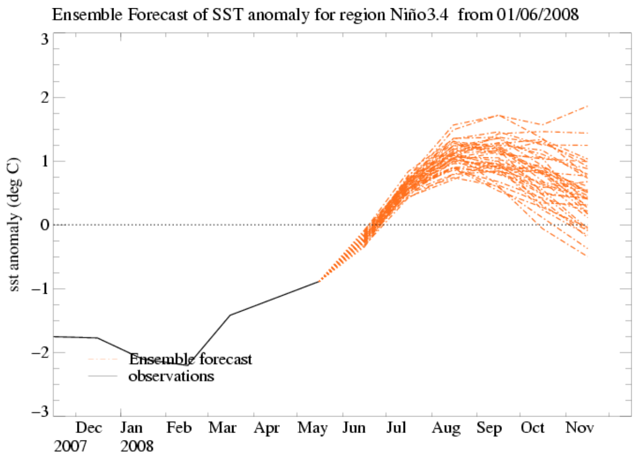

Figure 5: GloSea forecast for Niño3.4 (5˚S to 5˚N; 120˚W to 170˚W) monthly SST anomalies initialised 1st June 2008. Anomalies are relative to the 1987-2001 period. Red lines show the predicted SST evolution of the individual GloSea ensemble members. The black line shows observed anomalies. The spread in the ensemble 'plume' provides a measure of the prediction uncertainty.

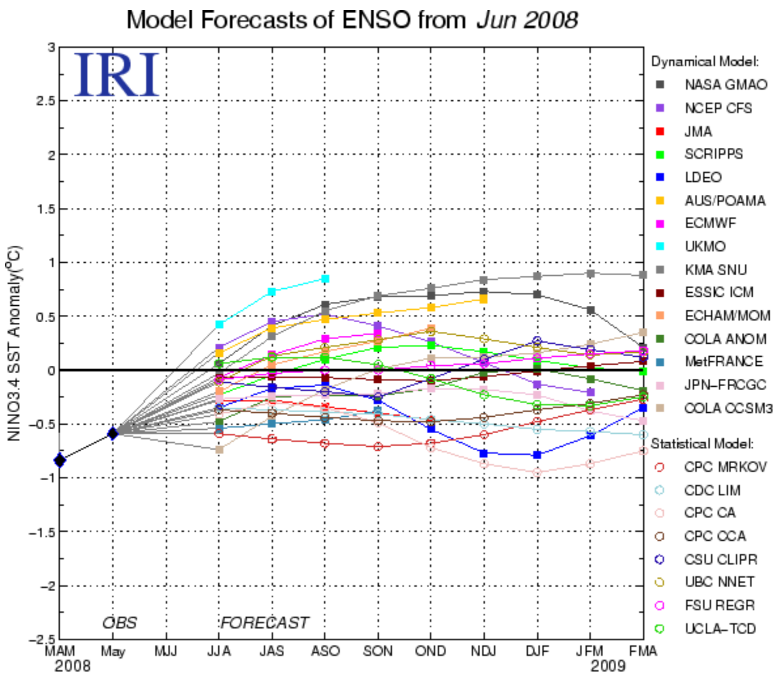

Figure 6: Forecasts of tropical Pacific SST anomalies from a range of dynamical and statistical prediction systems (from IRI, http://iri.columbia.edu)

6. Forecast verification

Ensemble mean retrospective forecasts ('re-forecasts') for the period 1987-2007 are compared with observations in Fig. 7 for both storm numbers and ACE index. The re-forecasts are made with the same method used for the 2008 forecast, except that a smaller 15-member ensemble is used. The so-called cross-validation procedure is employed in which no observed information for the year being predicted is used in the calibration process – in order that the re-forecasts are consistent with the constraints of an operational environment. More detailed re-forecast information is provided for 2005, 2006 and 2007 in Appendix B. The inter-annual variability of storm numbers (Fig. 7a) and ACE index (Fig. 7b) is generally well predicted, with correlations against observations of 0.64 and 0.62 respectively (Note: higher correlations for GloSea predicted storm numbers are found for the shorter period, 1993-2006 – see Table 3). The active seasons of 1995 and 2005 are generally well signalled in the forecast storm numbers (Fig. 7a). The observed number in 2005 (24) is underestimated by the ensemble mean (18), but is within the predicted range (8 to 29) (see Appendix B, Table 5). Relatively high values of ACE index are successfully identified for 1989, 1995 and 1998 (Fig. 7b), but the ACE index forecast for 2005 is less successful, showing a substantial underprediction.

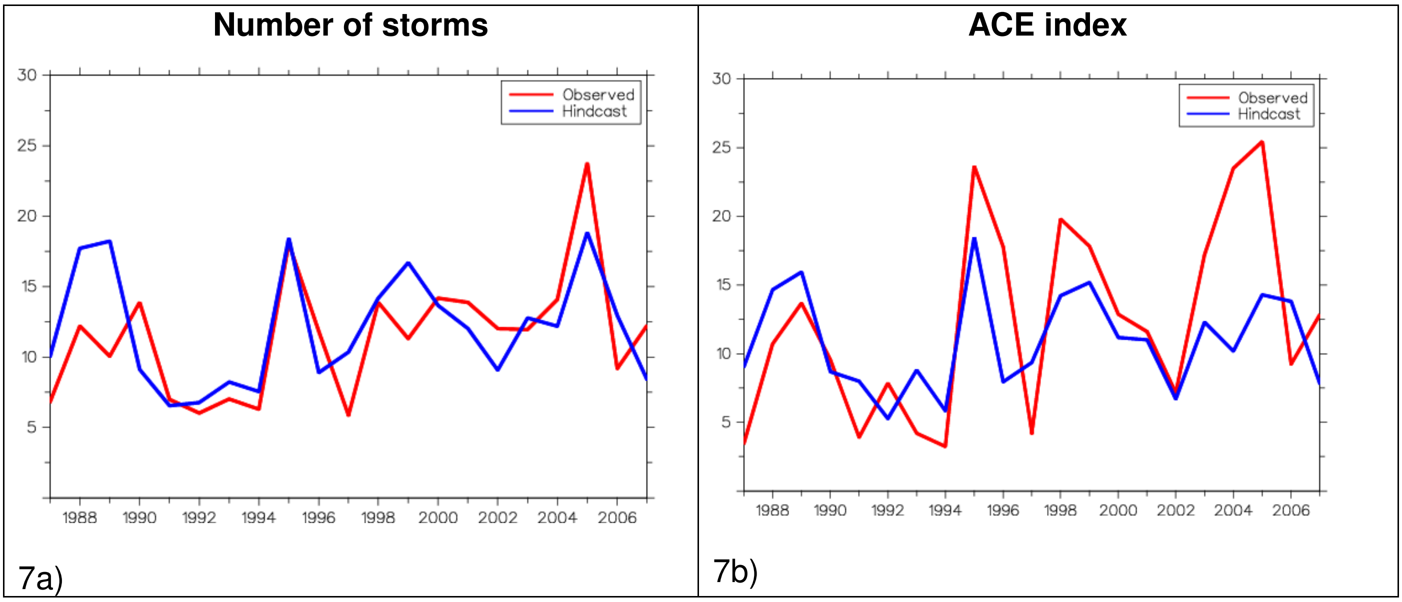

Figure 7: Ensemble-mean forecasts (blue) and observations (red) of a) tropical storm numbers and (b) ACE index for July to November periods 1987-2007. Forecasts are initialised in June. Observed values are from the HURDAT dataset.

The GloSea ensemble-mean forecasts of tropical storm numbers perform well in comparison with the statistical forecasts of the Colorado State University and University College London's Tropical Storm Risk. A published comparison of scores for the period 1993-2006 (Vitart et al., 2007) is shown in Table 3. The GloSea correlation score in Table 3 was calculated using a slightly different calibration method in use at the time, however the same value (0.78) is achieved with the revised calibration method used for the 2008 forecast. The higher GloSea correlation score (relative to the statistical methods) highlights the model's ability to get the phase of year-on-year fluctuations in the number of storms correct, whilst the lower root mean square (RMS) error highlights that the size of those fluctuations is also in closer accord with observations.

	GloSea	Tropical Storm Risk	Colorado State University
Correlation	0.78	0.65	0.39

Best = 1.0			
RMS error Best = 0.0	3.65	4.7	4.76

Table 3: Correlation and root mean square error performance measures for the number of Atlantic tropical storms predicted by the Met Office dynamical seasonal model, TSR and CSU, compared with the observed number of tropical storms during the whole Atlantic season (taken from http://www.nhc.noaa.gov) over the period 1993-2006. Note: the GloSea calibration score for this period obtained with the revised calibration method used for the 2008 forecast is also 0.78.

As mentioned previously, the success of the dynamical model forecasts is rooted in good prediction skill for SST in the equatorial Pacific and tropical North Atlantic oceans. Measures of prediction skill for June forecasts of August-September-October mean SST are provided for ensemble-mean forecasts in Table 4 and for probability forecasts in Fig. 8.

Ensemble-mean forecasts and observations have a correlation exceeding 0.8 in both regions (Table 4). Probability forecasts for SST anomalies, based on the ensemble distribution, also show good skill. This is illustrated in Fig. 8, which provides a global assessment of retrospective probabilistic forecasts for August-September-October SST above the upper tercile (the upper tercile is the SST value exceeded in one third of years). The skill measure used is the Relative Operating Characteristic (ROC), a standard measure recommended by the World Meteorological Organisation for assessment of probabilistic forecasts. ROC scores of 0.7 and above are shaded yellow to red, and correspond to regions with significant skill levels. It may be seen that the equatorial Pacific and tropical North Atlantic, where the seasonal model predicts warm anomalies for the 2008 season, are both regions where the model has demonstrated a good performance track record (ROC scores exceed 0.7).

	Equatorial Pacific (Niño3.4: 5˚S-5˚N;120˚W-170˚W)	Tropical North Atlantic (10˚N-30˚N; 5˚W-85˚W)
Correlation Best = 1.0	0.84	0.88
RMS error Best = 0.0	0.67˚C	0.13˚C

Table 4: C*orrelation and root mean square error performance measures for ensemble-mean predictions of August-September-October SST in the equatorial Pacific and tropical North Atlantic. Results are from retrospective forecasts for the 1987-2005 period.*

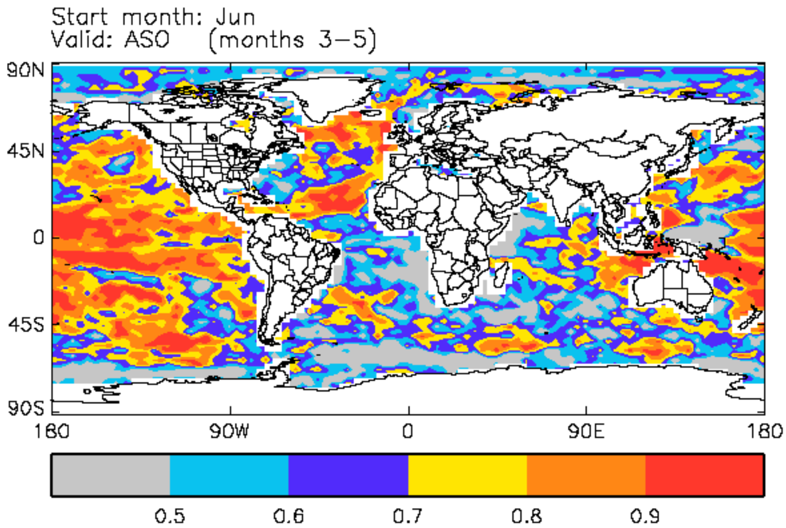

Figure 8: Relative Operating Characteristic (ROC) scores for June probability forecasts of August-September-October SST above the upper tercile. Scores are evaluated using retrospective forecasts for the 1987-2002 period. Regions with ROC score equal to or greater than 0.7, 0.8 and 0.9 are coloured yellow, orange and red respectively - and indicate regions with relatively good seasonal prediction skill (perfect forecasts would attain a ROC score of 1.0). Regions with ROC score between 0.6 and 0.7 show skill at lower levels but still better than guessing or use of climatology. Grey or light blue shading is used when scores are below 0.6, suggesting forecasts in these regions are currently little better than guesswork. (Note: a ROC score of 0.5 or below indicates no forecast skill in detecting the event – where in this case the event is SST above the upper tercile).

7. Future forecasts and feedback

Long-range tropical storm forecasts are very important for many market sectors. Given this, the Met Office is committed to developing a full range of tropical storm forecast products in a way that best meets its customers' needs. Scientific rigour is a key aspect of our heritage – and we look forward to improving and developing the science with our business and public customers.

The Met Office is ideally placed to provide risk-based forecast information on tropical storms on a full range of timescales from hours to decades ahead. Forecasts from the Met Office's global short-range model predicted the formation of sub-tropical storm Andrea in May 2007, a full 60 hours before any other model. The short-range model has also proved its worth in predicting hurricane landfall (accurately predicting the landfall of Katrina in 2005 12 hours ahead of other models). The Met Office short-range global model was one of the top two models for the prediction of Atlantic tropical storm tracks in 2007 (Franklin, 2008). The model achieved a greater accuracy at all lead times out to five days ahead than in any previous year for this region.

This same technology is used on seasonal timescales through our integrated Unified Model – where both weather and climate scientists work together to improve both short-term and long-term predictions. The Met Office Hadley Centre has developed new dynamical models for the Intergovernmental Panel on Climate Change assessment, and these are now being tested on timescales from seasonal to decadal ranges – all with a risk-based probabilistic and verifiable approach. In this way, the full range of climate change impacts will be included in our forecasts – whether they are for the year 2100 or for tomorrow.

To assist in this process, we would like to develop long-standing and supportive relationships with our commercial clients to ensure that the forecasts are suitable for business as well as public use. Any feedback is welcome – contact details are below.

Appendix A - The Met Office seasonal dynamical prediction system, GloSea

The GloSea seasonal prediction system is a coupled ocean-atmosphere General Circulation Model (GCM), similar to the HadCM3 climate version of the Met Office Unified Model, with a number of enhancements for seasonal forecasting purposes. Details of the model physics and discussion of the performance of HadCM3 can be found in Gordon et al. (2000). A performance assessment for temperature prediction may be found in Graham et al. (2005).

The atmospheric component of the system (see Pope et al. (2000) for a description), has a horizontal resolution of 3.75° east-west and 2.5° north-south, and 19 vertical levels. The oceanic component has 40 vertical levels, zonal grid spacing at 1.25°, and meridional grid spacing of 0.3° near the equator increasing to 1.25° poleward of the mid-latitudes (compared to 1.25° resolution east-west and north-south in HadCM3). A coastal tiling scheme has been included which enables specification of the land-sea mask at the ocean resolution, rather than the coarser atmosphere resolution. This allows a relatively detailed representation of the land-sea boundaries – which can be important in the evolution of SST anomalies. Like HadCM3, the seasonal coupled GCM contains no flux corrections or relaxations to climatology.

Each forecast requires initial ocean, land and atmosphere conditions. The land and atmosphere conditions are specified from atmospheric analyses that are produced separately for weather prediction purposes. The ocean initial conditions are taken from ocean analyses generated specifically for seasonal forecasting, using the ocean GCM component of the system. To generate the ocean analyses, the ocean GCM is run using surface fluxes of momentum, heat and water prescribed from atmospheric analyses, while assimilating sub-surface ocean observational data, with temperatures in the top layers constrained to be close to surface observations.

GloSea forecasts to 6 months ahead are made each month using initial conditions valid for the beginning of the month. The initial conditions are perturbed to create starting conditions for the 41-member ensemble. The perturbations are created during the construction of the ocean analysis by varying the surface momentum fluxes by amounts that represent the observed uncertainty in this quantity. Perturbations are additionally applied to SST, again to represent the observed uncertainty in observation of SST. Over the 6-month forecast the evolution of the 41 individual members will diverge. The spread in the forecast represents the prediction uncertainty arising from uncertainty in the initial conditions.

Appendix B – Equivalent detailed re-forecast information for 2005, 2006 and 2007

Re-forecasts for the last three Atlantic seasons (July to November) are provided here for comparison with the 2008 forecast. The re-forecasts have been made retrospectively using the same method as used for the 2008 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.

For 2007 the observed number of storms (12) was within the two-standard-deviation forecast range of 5-13 (Table 5). 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 low ACE index was well predicted by the ensemble mean (Table 5) and the potential for a low value was clearly indicated in the probability forecast for ACE index (Fig. 9b), which showed an enhanced probability (57.5%) of an ACE index of less than 70 (an index of 71 was observed).

The contrast between the exceptionally active 2005 season (24 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. 11a), while for 2006 the peak forecast probability is for the climatological mode of 10-12 storms (Fig. 10a). The observed difference between the 2005 and 2006 seasons is less well represented in the ACE forecasts. In particular, for 2005 (Fig. 11b), the largest predicted probability was for the 70-99 ACE index category (the observed value was 257). However, the 2005 forecast did indicate that the probabilities for ACE index in the 160-189 and 190-219 categories were marginally greater than the climate probability. In contrast, predicted probabilities for these active categories for the 2007 and 2006 seasons (Figs. 9b and 10b) were less than the climatological chance, correctly signalling the lower observed activity in those seasons.

	No. of storms			ACE index		
	EM	2 sd range	Observed	EM	2 sd range	Observed
2007	9	5 – 13	12	69	48 - 90	71
2006	13	10 – 17	9	111	86 - 135	91
2005	18	8 – 29	24	132	72 - 191	257

Table 5: Ensemble mean (EM) forecasts and observations for 2005, 2006 and 2007 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 2008 forecast. (Note the 2005 forecast used a smaller ensemble of 15 members, the smaller ensemble size is partly responsible for the large two-standard-deviation (2 sd) range predicted for that year. Also, the ensemble-mean value and two-standard-deviation range for 2007 differ slightly from the values issued operationally last year, because of small changes to the forecast calibration.

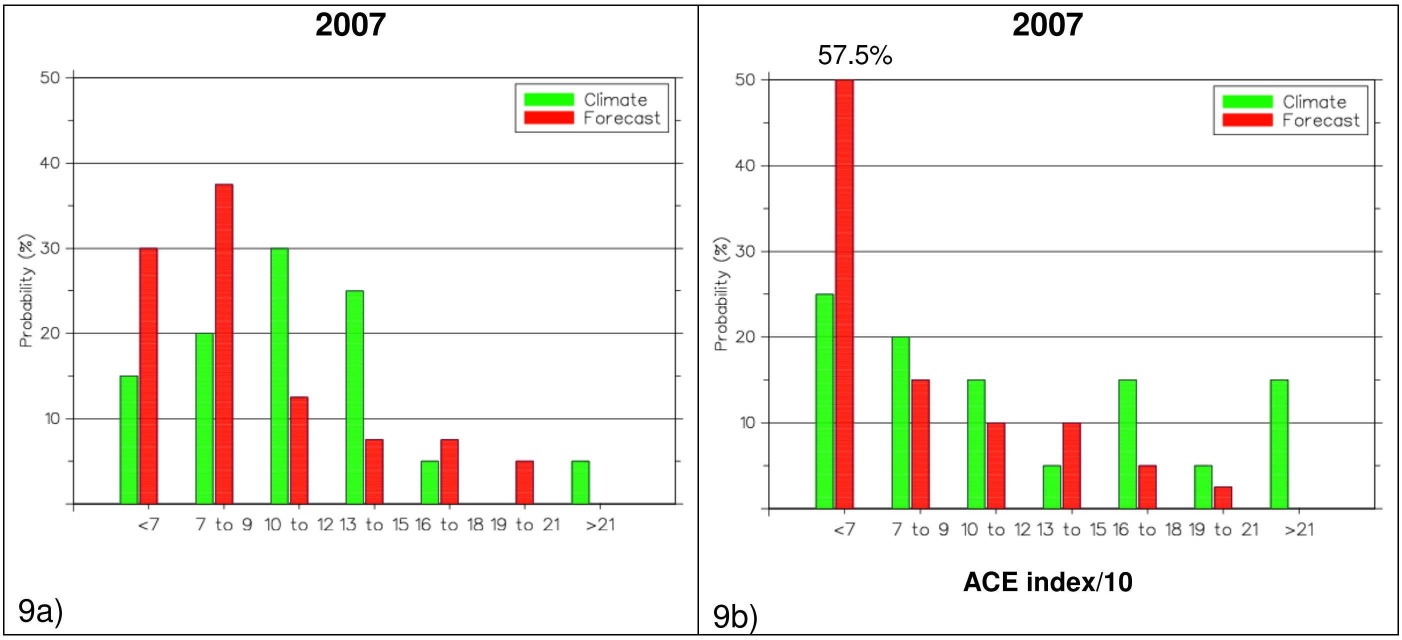

Figure 9: a) Forecast probability that the number of Atlantic sector tropical storms, in the July to November 2007 period, will lie within given ranges. Red = forecast probabilities for 2007; green = climatological frequencies derived from observations, 1987 – 2006. b) As a), but for ACE index. For presentation purposes the ACE index values have been divided by 10, and the upper value of the ACE index range is displayed truncated (e.g. 7 to 9 refers to an ACE index range of 70 to 99, strictly 70 ≤ ACE index < 100). Tropical storm numbers and ACE index values are from the NOAA HURDAT dataset.

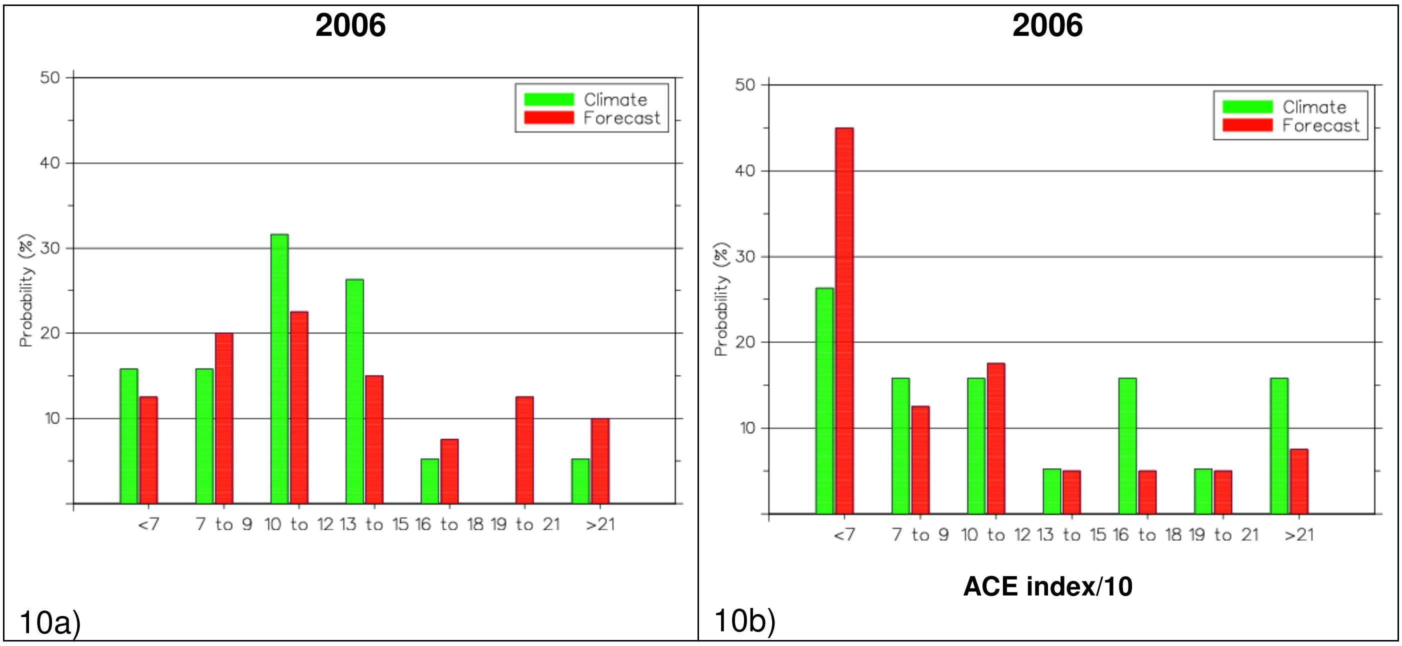

Figure 10: As Fig. 9, but for 2006. Climatological frequencies are based on 1987-2005.

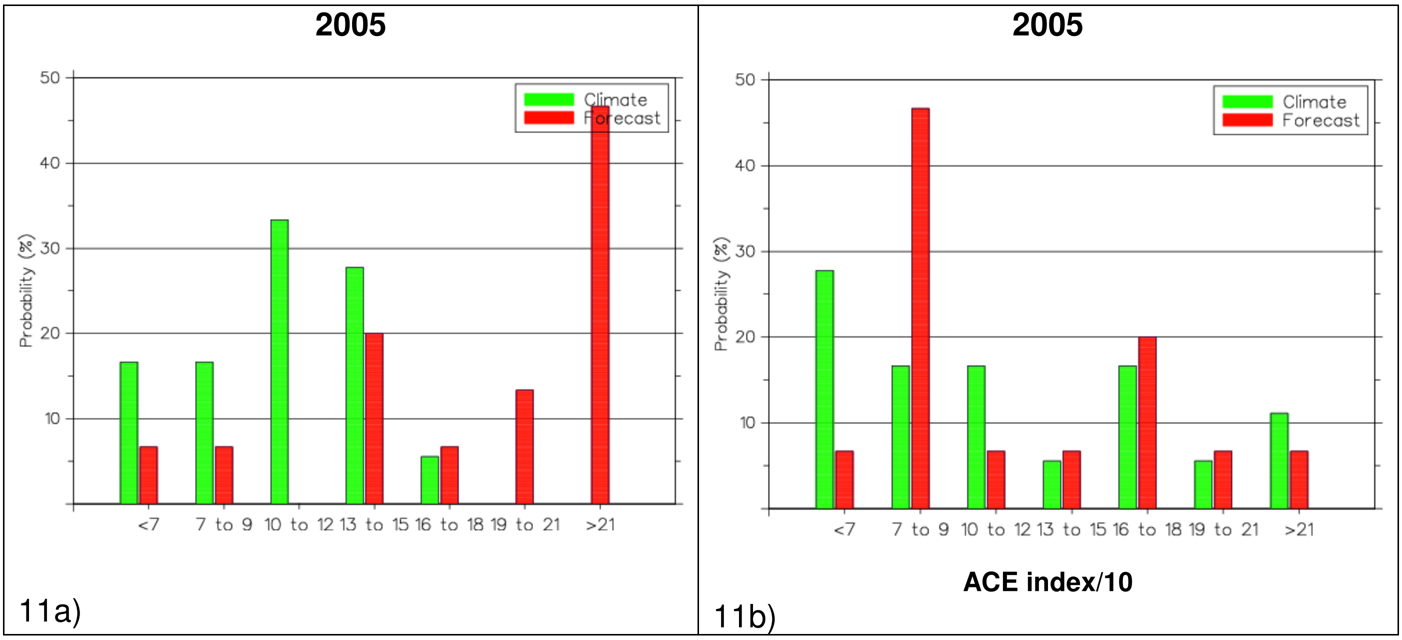

Figure 11: As Fig. 9, but for 2005. Climatological frequencies are based on 1987-2004.

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Please note that our hurricane predictions are inexact; they are based upon the evolving knowledge of the weather and climate research community at the time they are made and their accuracy cannot be guaranteed.