P1.94 SEASONAL PREDICTION OF ACCUMULATED CYCLONE ENERGY IN THE NORTH ATLANTIC

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1. INTRODUCTION

Seasonal forecasts of tropical storm activity in the North Atlantic have focused on predicting the individual numbers of tropical storms, hurricanes and intense hurricanes; these numbers being indicative of the basin's overall seasonal activity. Recently NOAA have introduced the Accumulated Cyclone Energy (ACE) index as a measure which is arguably more appropriate for representing the overall wind energy and thus activity of a season (Waple et al., 2001). The ACE index reflects a combination of intensity and duration of all tropical storms during the season and is defined as the sum of the squares of 6-hourly maximum sustained wind speeds (measured in knots) for all systems while they are at least tropical storm strength.

Here we describe the prediction scheme developed by the Tropical Storm Risk (TSR) forecasting venture to seasonally predict the Atlantic total ACE index. We examine the seasonal predictability of this index for the 1950-2003 54-year extended period of reliable environmental data. Monthly leads out to 10 months taken from the start of the main Atlantic hurricane season on 1 August are considered. The paper also summarises the TSR current forecast for the Atlantic total ACE index in 2004, and suggests how seasonal skill for this index may be further improved.

2. DATA AND METHODOLOGY

Tropical storm and hurricane 6-hourly maximum sustained wind data are obtained from the US National Hurricane Center's North Atlantic hurricane database (Neumann et al., 1999). Environmental field data are obtained from the NCEP/NCAR global reanalysis project. We examine the period 1950-2003.

The Atlantic basin is divided into three sub-regions: (a) the Atlantic Hurricane Main Development Region MDR (10ºN-20ºN, 20ºW-60ºW), (b) the Caribbean Sea and the Gulf of Mexico, and (c) the Extra-Tropical north Atlantic. The hindcast Atlantic total ACE index comprises the sum of separate ACE index hindcasts for regions (a) and (b), combined with a 54-year climatology for region (c).

The TSR ACE index forecast model is statistical. It employs two predictors which are physically sound, uses linear regression, and assesses hindcast skill using the methodology recommended by the World Meteorological Organisation (WMO) for verification of seasonal deterministic forecasts (WMO, 2002).

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3. ATLANTIC TOTAL ACE INDEX PREDICTORS

The two total ACE index predictors are:

A) The July-August-September forecast 925mb *u*-wind (zonal or east-west wind) or trade wind speed over the Caribbean and tropical north Atlantic (region 7.5ºN-17.5ºN, 30ºW-100ºW). This is predicted using August-September forecast ENSO sea surface temperatures (SSTs) and August-September Atlantic/Caribbean forecast SSTs for the regions 5S-5ºN, 90ºW-160ºE, and 7.5ºN-17.5ºN, 40ºW-85ºW respectively. The 925mb *u*-wind is a strong proxy for vertical wind shear over this sector but is more predictable. The ENSO SST prediction model is a 'consolidated' 18-member ensemble version (Lloyd-Hughes et al., 2004) of the statistical ENSO-CLIPER model. The prediction model for the Atlantic/Caribbean SST region is a statistical principal component model which employs the lagged initial conditions of the leading mode of North Atlantic SST variability.

B) The August-September forecast SST for the Atlantic Hurricane Main Development Region MDR (10ºN-20ºN, 20ºW-60ºW). These SSTs are forecast using the same principal component model described above. Warm SSTs are linked to high total ACE index.

The modelled total ACE index obtained by exactly forecasting these two fields agrees soundly with the actual total ACE index 1950-2003 (Figure 1). The modelled ACE index replicates the interannual and multi-decadal variability present in the observed record. The observed and modelled total ACE index timeseries in Figure 1 have a correlation of 0.78.

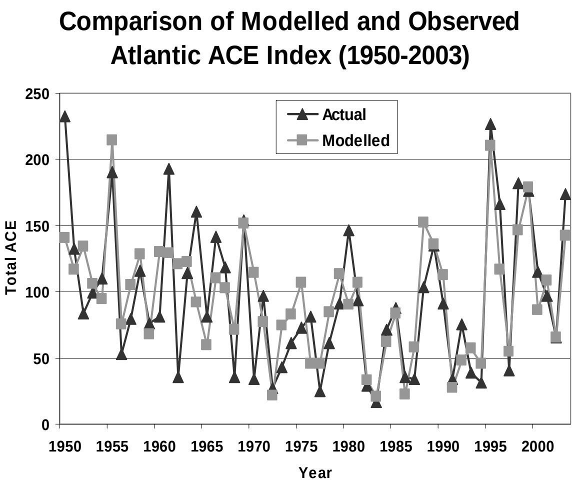

Figure 1. Time series 1950-2003 of actual Atlantic total ACE index versus modelled Atlantic ACE index based on perfect knowledge of the two predictors.

4. SKILL SCORE AND UNCERTAINTY

Seasonal predictability of the Atlantic ACE index 1950-2003 is assessed using cross-validated hindcasts with block elimination. At each step a new model is formulated trained on all data excluding a 5 year block centred on the year of interest. This block is tapered at the time series ends. Block elimination is employed to minimise potential skill inflation which may arise from multi-annual persistence.

Hindcast skill is computed using the mean square skill score (MSSS) defined as the percentage reduction in mean square error of the model hindcasts compared to hindcasts made with the 1950-2003 climatology value. MSSS is the skill metric recommended by the WMO for verification of deterministic seasonal forecasts (WMO, 2002). It is a robust skill measure which is immune to the bias problems associated with other measures. Positive (negative) skill indicates that the model is doing better (worse) than climatology.

Confidence intervals are computed on the forecast skill using the bootstrap method (Efron and Gong, 1983). This tests the hypothesis that the model forecasts are more skilful than those from climatology to some level of significance over the period in question.

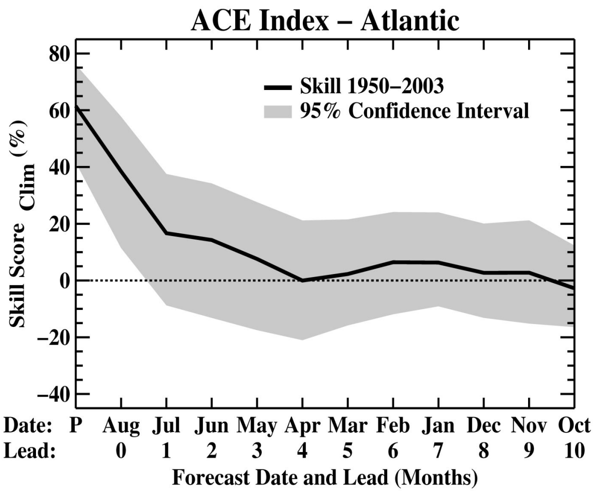

Figure 2. TSR cross-validated hindcast skill 1950-2003 as a function of forecast date and lead time out to 10 months. The skill measure used is the mean square skill score (MSSS) defined as the percentage improvement in mean square error over a hindcast of zero anomaly; the climatology being 1950-2003.

5. TSR CROSS-VALIDATED HINDCAST SKILL

Figure 2 displays the cross-validated hindcast skill for the Atlantic total ACE index 1950-2003. The ‘P’ on the abscissa denotes the skill with perfect predictors, that is, knowing perfectly the values for the two predictors (section 3). The August MSSS value is 37% and this is positive to >99% confidence. By early July skill has reduced to 17% and this is positive to only 90% confidence. At leads greater than 3 months (early May) little skill is found for predicting the total ACE index 1950-2003.

6. 2004 FORECAST

At the time of writing (February 2004) the TSR forecast anticipates that the Atlantic total ACE index in 2004 will be above average (defined as an ACE index value in the upper tercile historically (>108)) to 72% probability. Based on data through the end of January 2004 TSR anticipates an ACE index of 139±53 knots^{2}x10^4. Both predictors (trade wind speed and tropical North Atlantic SST) are expected to have a slight to moderate enhancing affect on hurricane activity in 2004. The TSR forecasts will be updated monthly through to August 2004 and are available from www.tropicalstormrisk.com.

7. SUMMARY AND FUTURE WORK

We have shown that over the extended period 1950-2003 there is skill to >99% confidence in predicting from 1 August the overall activity of the Atlantic hurricane season represented by the ACE index. The MSSS for 1 August hindcasts 1950-2003 of the total ACE index is 37%. TSR is continuing to expand its services and to further improve the scientific and technical basis of its forecasts. For the 2004 Atlantic hurricane season TSR will be releasing an improved model for predicting the US landfalling ACE index. Further research is examining whether use of seasonal forecasts from the ECMWF, Meteo France and UK Met Office dynamical models for the two ACE index predictors (tropical North Atlantic and Caribbean Sea trade wind speed and tropical North Atlantic SST) will improve skill for the Atlantic total ACE index at leads of 0 and 3 months.

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8. REFERENCES

Efron, B. and G. Gong, 1983: A leisurely look at the bootstrap, the jackknife, and cross-validation, *The American Statistician*, **37**, 36-48.

Lloyd-Hughes, B., M. A. Saunders and P. Rockett, 2004: A consolidated CLIPER model for improved August-September ENSO prediction skill, *Wea Forecasting, submitted.*

Neumann, C. J., B. R. Jarvinen, C. J. McAdie and G. R. Hammer, 1999: Tropical Cyclones of the North Atlantic Ocean, 1871-1999, *NOAA/NWS/NESDIS, Historical Climatology Series 6-2*, 206 pp.

Waple, A. M. et al., 2001: Climate assessment for 2001, *Bull. Amer. Meteor. Soc*., **83**, S1.

WMO, 2002: Standardised verification system for long-range forecasts (LRF): new attachment II-9 to the manual on the GDPS, *WMO No. 485, Volume 1*, WMO, Geneva.