6B.4 REVISED PREDICTION OF SEASONAL ATLANTIC BASIN TROPICAL CYCLONE ACTIVITY FROM 1 AUGUST

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1. INTRODUCTION

The Tropical Meteorology Project (TMP) at Colorado State University has been issuing Atlantic basin seasonal hurricane forecasts since 1984 (Gray 1984a, b). These forecast techniques have undergone considerable revisions over the past 25 years. Early August predictions, although two months into the hurricane season, are generally regarded as a seasonal forecast, since typically only about 5% of a season's Accumulated Cyclone Energy (ACE) or Net Tropical Cyclone (NTC) activity occurs during June-July. Using newly-generated datasets, I attempt to develop an early August forecast scheme that utilizes data extending back to 1900. Extensive documentation of this new scheme has recently been published in Klotzbach (2007). This pre-print summarizes the findings documented more fully in Klotzbach (2007) and includes some more recent developments.

2. DATA

NCEP/NCAR reanalysis data was the primary source for predictive variables for the 1949-2005 period (Kistler et al. 2001). Only surface predictors (i.e., sea surface temperature, sea level pressure, etc.) were considered, since these data are available back to 1900, although of likely somewhat reduced quality. In order to assess the viability of predictors on the first portion of the 20th century, additional datasets were utilized. Sea level pressure values from 1900-1948 were taken from the Hadley Center SLP dataset (Basnett and Parker 1997), while sea surface temperature values from 1900-1948 were taken from the Kaplan SST dataset (Kaplan et al. 1998).

Atlantic basin hurricane activity from 1900-2005 was calculated from the National Hurricane Center's best track dataset (Jarvinen et al. 1984). Recent changes made by Chris Landsea and colleagues as part of the Atlantic Hurricane Database Reanalysis Project for tropical cyclones from 1900-1914 have been included (Landsea et al. 2004).

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3. METHODOLOGY AND RESULTS

In a method that deviates somewhat from previous seasonal prediction efforts at the TMP, predictors were selected using a stepwise regression technique. These predictors were required to explain considerable amounts of variance explained over the developmental period from 1949-1989, as well as over a more recent "independent" period from 1990-2005 and an earlier "independent" period from 1900-1948. In addition, all parameters were found to individually correlate significantly at the 95% level with post 1-August Net Tropical Cyclone activity over each of the time periods that were investigated.

Instead of attempting to hindcast several seasonal parameters such as named storms and major hurricane days (e.g., Klotzbach and Gray 2004), I instead evaluated predictors that explained considerable amounts of variance in post 1-August Net Tropical Cyclone (NTC) activity. Table 1 displays the four predictors that were selected by this approach, while Table 2 displays the variance explained by these predictors over the various periods of 1949-1989, 1990-2005, 1900-1948 and 1900-2005, respectively. Note that the addition of each predictor explained additional amounts of variance in each of the individual hindcast/forecast periods. Additional details on the predictor selection process along with likely physical relationships between individual predictors and Atlantic basin tropical cyclone activity are discussed in Klotzbach (2007).

Table 1: Listing and location of predictors utilized in the early August seasonal forecast.

Predictor Name	Location
1) June-July SST in the Subtropical Atlantic	(20°-40°N, 35°-15°W)
2) June-July SLP in the Tropical and Subtropical Atlantic	(10°-20°N, 60°-10°W)
3) June-July Nino 3 SST Index	(5°S-5°N, 150°-90°W)
4) Before 1 August Tropical Atlantic Named Storm Days	(South of 23.5°N, east of 75°W)

Table 2: Variance explained for post-1 August by adding predictors to the forecast scheme. Predictor numbers are as given in Table 1.

Predictors	1949-1989	1990-2005	1900-1948	1949-2005	1900-2005
1	0.16	0.41	0.23	0.25	0.32
1, 2	0.39	0.56	0.32	0.37	0.45
1, 2, 3	0.43	0.67	0.38	0.41	0.51
1, 2, 3, 4	0.45	0.71	0.45	0.49	0.60

Figure 1 displays observed versus hindcast post-1 August NTC for the period from 1949-2005. Non-jackknife variance explained over the period was 52%. Using the exact same equations developed over the 1949-1989 period to forecast 1900-1948 results in forecasts with slightly reduced levels of variance explained (r^2 = 0.45). This is actually slightly higher than would be expected from jackknife regression (r^2 = 0.42) (Elsner and Schmertmann 1994). The scheme consistently over-predicts NTC over the 1900-1948 period using equations developed over 1949-1989. The mean for observed NTC from 1900-1948 was 68, while the scheme predicts 97. This over-prediction is likely due to under-estimation of tropical cyclone activity during the first half of the 20th century, due to lack of satellite imagery and aircraft reconnaissance. Figure 2 displays observed versus hindcast post 1-August NTC from 1900-1948 using equations developed over the same period (1900-1948), in order to more accurately predict NTC values during this time period.

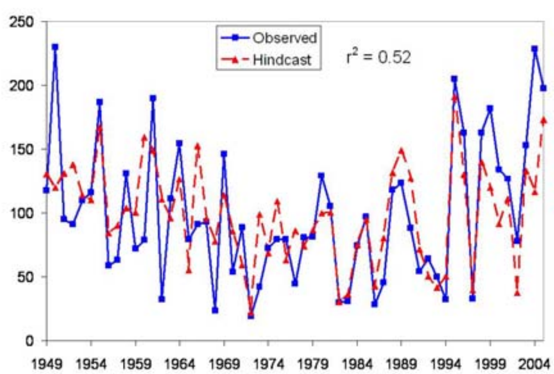

Figure 1: Observed versus post-1 August NTC activity over the period from 1949-2005. Hindcast values are the red dashed line, while observed values are the solid blue line. Non-jackknife variance explained over the period is 52%.

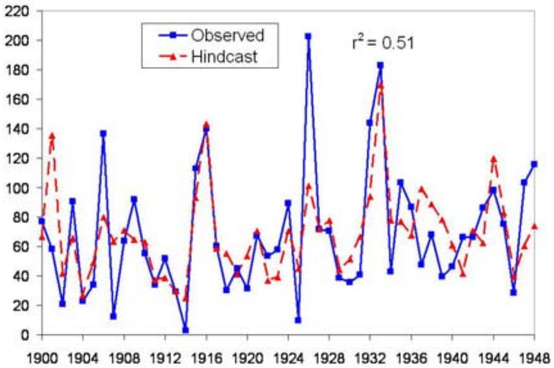

Figure 2: Observed versus post-1 August NTC activity over the period from 1900-1948. Hindcast values are the red dashed line, while observed values are the solid blue line. Non-jackknife variance explained over the period is 51%.

4. RECENT DEVELOPMENTS AND LANDFALL APPLICATIONS

Additional development of the August seasonal forecast has taken place since Klotzbach (2007). By using a combination of the early June seasonal forecast scheme and the early August seasonal forecast scheme, additional variance can be explained over the 1950-2007 period. By weighing the August forecast NTC value as 60% of the final number and the June forecast NTC (less June-July observed activity) as 40% of the final number, variance explained for NTC over the period from 1950-2007 rises considerably to 66% of the variance. Figure 3 displays observed versus post-1 August NTC hindcasts over the period from 1950-2007 using this new method. Documentation on our newly-developed June forecast scheme will be forthcoming with our early June prediction for 2008 hurricane activity.

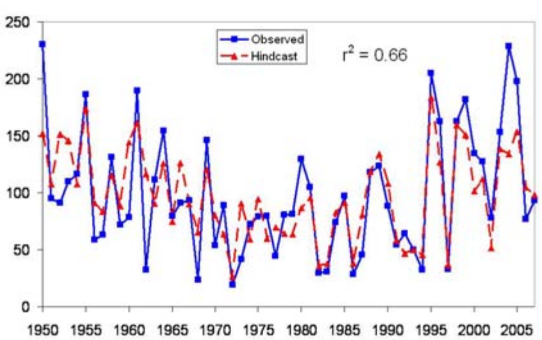

Figure 3: Observed versus post-1 August NTC activity over the period from 1950-2007 using the new scheme. Hindcast values are the red dashed line, while observed

values are the solid blue line. Non-jackknife variance explained over the period is 66%.

United States landfalls tend to be much more frequent during active seasons than during inactive seasons. Since our new August seasonal forecast explains a large amount of the variance in seasonal NTC, it is to be expected that considerable ratios in U.S. landfall will exist between years that active seasons are hindcast compared with years that inactive seasons. Are hindcast For example, during the 10 years that the largest values of NTC were hindcast, 11 hurricanes made landfall along the Gulf Coast after 1 August compared with only 4 hurricanes making landfall after 1 August along the Gulf Coast in the 10 years that the smallest values of NTC were hindcast. Ratios are even more considerable along the Florida Peninsula and East Coast. Eleven major hurricanes made landfall after 1 August during the 15 years where the largest values of NTC were hindcast, compared with only two major hurricanes making landfall after 1 August during the 15 years where the smallest values of NTC were hindcast. Figure 4 displays the tracks of major hurricanes making Florida Peninsula and East Coast landfall after 1 August in the top 15 NTC hindcast years compared with the bottom 15 NTC hindcast years.

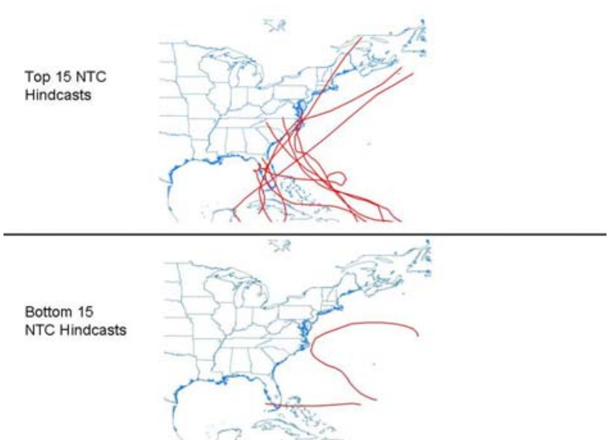

Figure 4: Tracks of major hurricanes making Florida Peninsula and East Coast landfall after 1 August in the top 15 NTC hindcasts compared with the bottom 15 NTC hindcasts. Eleven major hurricanes made landfall in the top 15 NTC hindcasts compared with two major hurricanes making landfall in the bottom 15 NTC hindcasts.

5. FUTURE WORK AND CONCLUSIONS

The TMP continues to work on improving the hindcast skill and hopefully the real-time forecast skill of all of its seasonal forecasts. In the next few months, I intend to examine the skill of the June-August combination scheme over the first part of the 20th century. Also, additional insights into the relationship between each predictor and seasonal hurricane activity will be sought.

There is inherent curiosity amongst the general public as to how active or inactive the hurricane season is likely to be. By developing statistical forecast schemes that show considerable skill on over one century's worth of data, it is to be hoped that these forecasts will show "real-time" forecast skill in the future. These statistical forecasts showed considerable skill in both 2006 and 2007 (see Figure 3), and we intend to place much more confidence in these predictions in the future.

6. REFERENCES

Basnett, T. and D. Parker, 1997: Development of the global mean sea level pressure data set GMSLP2, *Climate Research Technical Note,* **79**, Hadley Centre Met Office, Exeter, UK.

Elsner, J. B., and C. P. Schmertmann, 1994: Assessing forecast skill through cross validating. *Wea. Forecasting,* **9,** 619-624.

Gray, W. M., 1984a: Atlantic seasonal hurricane frequency. Part I: El Niño and 30 mb quasi-biennial oscillation influence. *Mon. Wea. Rev.,* **112,** 1649-1668.

Gray, W. M., 1984b: Atlantic seasonal hurricane frequency. Part II: Forecasting its variability. *Mon. Wea. Rev.,* **112,** 1669-1683.

Jarvinen, B. R., C. J. Neumann, and M. A. S. Davis, 1984: A tropical cyclone data tape for the North Atlantic basin, 1886-1983: Contents, limitations, and uses. NOAA Tech. Memo., 21 pp.

Kaplan, A., M. Cane, Y. Kushnir, A. Clement, M. Blumenthal, and B. Rajagopalan, 1998: Analyses of global sea surface temperature 1856-1991. J. Geophys. Res., 103, 567–589.

Kistler, R., and Coauthors, 2001: The NCEP/NCAR 50-year reanalysis: Monthly means cd-rom and documentation. Bull. Amer. Meteor. Soc., 82, 247-267.

Klotzbach, P. J., 2007: Revised prediction of seasonal Atlantic basin tropical cyclone activity from 1 August. *Wea. Forecasting,* **22,** 937-949.

Klotzbach, P. J. and W. M. Gray, 2004: Updated 6-11-month prediction of Atlantic basin seasonal hurricane activity. Wea. Forecasting, 19, 917-934.

Landsea, C. W., C. Anderson, N. Charles, G. Clark, J. Dunion, J. Fernandez-Partagas, P. Hungerford, C. Neumann, and M. Zimmer, 2004: The Atlantic hurricane database re-analysis project: Documentation for the 1851-1910 alterations and additions to the HURDAT database. Hurricanes and Typhoons: Past, Present and Future, R. J. Murnane and K.-B. Liu, Eds., Columbia University Press, 177-221.