Forecasts for the 2001 North Atlantic hurricane season and verifications from the previous season

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1. Forecast methodologies

The two components of overall hurricane activity that we examine are the seasonal number of hurricanes (H) and the seasonal number of intense (or major) hurricanes (MH). To predict the number of hurricanes we use an ordinary-least-squares linear regression to estimate the number of tropical-only hurricanes ($\hat{H}_T$) to which we add a seasonal average number of baroclinically-enhanced hurricanes ($\bar{H}_B$). The model can be expressed as

$$\hat{H} = \bar{H}_B + \hat{H}_T,$$

where

$$\hat{H}_T = \beta_0 + \sum_{i=1}^{2} \beta_i x_i,$$

and where the β_i's are coefficients on the predictors as described in Hess et al. (1995). The two predictors include the 10-month forward extrapolation of the vertical shear of upper-level winds over the Caribbean (expressed in m/s) and the average rainfall anomaly from the Gulf of Guinea region of west Africa (expressed in standard deviations). These are two of the five predictors suggested in Gray et al. (1992).

To predict the number of major hurricanes we use a Poisson regression expressed as

$$\hat{MH} = \exp(\gamma_0 + \sum_{i=1}^{4} \gamma_i x_i),$$

where the γ's are the coefficients on the predictors and exp() is the exponential function. Details of this model are given in Elsner and Schmertmann (1993). Two of the four predictors of the major hurricane model are identical to those used in the tropical-only hurricane model. The additional two predictors include the average rainfall anomaly over the Sahel region of Africa (in standard deviations) and the 50 mb upper-level winds (in m/s).

In addition to basin-wide activity we predict activity in the Caribbean Sea, the Gulf of Mexico, and along the southeast (Cape Hatteras south to Key West) and entire U.S. coast. We use logistic regression to predict hurricane landfalls along the coast and the presence or absence of major hurricanes in the Gulf, Caribbean and along the entire coast. As with the approach taken for basin-wide major hurricane activity, we express the sub-basin forecasts in terms of probabilities (Lehmiller et al. 1997).

Logistic regression is a statistical model to predict yes/no events by estimating coefficients for several predictor variables. "Yes" indicates the occurrence of the event. Here we use

a maximum likelihood technique to obtain the coefficients. A logistic regression can be expressed as

$$\Pr = \frac{\exp(\alpha_0 + \sum_{i=1}^{n} \alpha_i x_i)}{1 + \exp(\alpha_0 + \sum_{i=1}^{n} \alpha_i x_i)},$$

where Pr is the probability of occurrence and the α_i's are the coefficients on the predictors. Only the model for Caribbean hurricanes (H_C) is statistically significant using data through November. The Caribbean hurricane model uses the two rainfall parameters (Gulf of Guinea and Sahel) as predictors.

2. Predictions for the 2001 hurricane season

Here we describe our predictions for the 2001 North Atlantic hurricane season. Regression coefficients are estimated from data over the period 1950–2000. These coefficients along with the new predictor values for 2001 are given in Table 1. The model indicates that there will be **6 hurricanes** during the 2001 North Atlantic season. The forecast is based on rounding the regression forecast of the number of tropical-only hurricanes to 3 and adding to this number the rounded number of baroclinically-enhanced (BE) hurricanes. The average number of BE hurricanes over the period 1950–2000 is 2.9. A forecast of intense hurricane activity based on the above regression coefficients is presented in the form of estimated probabilities. The 2001 probabilities are quite different from 2000 probabilities indicating a decreased likelihood of intense hurricane activity during 2001. The **expected number of intense hurricanes is 1**. More specifically, the Poisson model estimates that there is a 76% chance of observing less than 2 intense hurricanes during 2001.

The logistic model for occurrence of a hurricane in the Caribbean indicates a 25% chance of observing at least one hurricane during 2001 in this part of the North Atlantic basin. This is below the long-term average probability (1950–2000) of nearly 61%. No subjective adjustments are made to these forecasts. The forecast of near or slightly below average activity is based on negative rainfall values. Forecasts will be updated prior to the start of the 2001 hurricane season.

3. Verification of our forecasts for the 2000 hurricane season

Table 3 shows the predicted versus actual values from the 2000 North Atlantic hurricane season based on forecasts issued by our group at Florida State University (FSU). Overall our

Table 1: **Predictor values and model coefficients for hurricane activity for the 2001 North Atlantic season.**

i. Predictor Term in Equation	H_T β_i	MH γ_i	H_C α_i	x_i
0. constant	4.315	1.030	1.036	—
1. Aug–Nov 00 Gulf of Guinea rainfall	2.681	0.879	2.844	−0.50 sd
2. Aug–Sep 00 West Sahel rainfall	—	0.455	1.002	−0.70 sd
3. 50mb zonal wind at 10°N fcst for Sep 01	—	0.022	—	−12 ms^{-1}
4. 30mb zonal wind at 10°N fcst for Sep 01	—	—	—	−10 ms^{-1}
5. wind shear at 10°N fcst for Sep 01	−0.106	−0.033	—	+2 ms^{-1}

Table 2: **FSU's forecast of intense hurricane activity for the 2001 North Atlantic hurricane season.**

No. of Intense Hurricanes (IH)	0	1	2	3	4	≥ 5
2000 Forecast Probabilities	0.260	0.350	0.236	0.106	0.036	0.012
2001 Forecast Probabilities	0.389	0.367	0.173	0.055	0.013	0.003

Table 3: **Verification of FSU's 2000 hurricane season forecasts.**

	Month Issued				
Predictand	December	June	August	Climatology	Actual
Hurricane	5	7	4	5.9	8
Major Hurricane	2		2	2.2	3
H_C	34%			61%	Yes
IH_C			47%	48%	Yes
IH_G			39%	46%	No
H_{SE}			62%	44%	No
IH_{US}			31%	35%	No

performance was fair. The December and August models under forecast the observed level of overall activity, particularly the number of hurricanes. The number of major hurricanes was only slightly off the mark. Our June forecast, based on time-series analysis (Elsner et al. 1998), was considerably more accurate. Sub-basin activity was also somewhat different than predicted, though we correctly anticipated that neither the Gulf of Mexico nor the U.S. coast would get hit by a major hurricane during the 2000 season.

Table 4 lists the hurricanes of the 2000 North Atlantic hurricane season. There were 3 baroclinically influenced hurricanes; hurricanes Florence and Michael were baroclinically-initiated and hurricane Gordon was baroclinically enhanced (Elsner and Kara 1999). In addition, there were 5 tropical-only hurricanes, of which 3 were major. This is the first year since 1994 that no storm reached the coast at hurricane intensity.

4. Past performance

Although our group at FSU has been issuing seasonal hurricane forecasts since 1993, the earlier forecasts were issued only for the number of intense hurricanes. Table 5 shows the December forecast probabilities from the Poisson model over the past 8 years. The bold numbers indicate the verification. Forecasts were very good for the 1993, 1997, and 1999 seasons, good for the 1994 and 1995 seasons, fair for the 1998 and 2000 seasons, and poor for the 1996 season.

Table 4: **2000 North Atlantic hurricane season. Category refers to the Saffir/Simpson hurricane damage potential scale. Type refers to tropical-only (TO), baroclinically-initiated (BI), or baroclinically-enhanced (BE) as described in Elsner and Kara (1999). Dates refer to begin and end dates of the tropical storm. U.S. hurricane indicates whether or not the eyewall of the hurricane made landfall in the United States.**

Cat.	Type	Name	Dates	U.S. hurricane?
IH-3	TO	Alberto	August 4–23	No
H-1	TO	Debby	August 20–24	No
H-1	BI	Florence	September 11–17	No
H-1	BE	Gordon	September 15–18	No
IH-4	TO	Isaac	September 21–October 1	No
H-1	TO	Joyce	September 25–October 2	No
IH-4	TO	Keith	September 29–October 6	No
H-2	BI	Michael	October 17–19	No

Table 5: **Performance record of FSU's December major hurricane model. Bold number indicate the actual number of major hurricanes. Climatology is based on the years 1886–1996. Past performance does not guarantee future success.**

IH	Climate	1993	1994	1995	1996	1997	1998	1999	2000
0	15.0	16.8	**15.9**	4.7	25.9	16.0	35.5	2.8	18.4
1	28.4	**29.9**	29.2	14.4	35.0	**29.4**	36.8	10.1	31.2
2	27.0	26.7	26.9	22.0	23.6	26.9	19.0	18.0	26.4
3	17.1	15.9	16.5	22.4	10.7	16.4	**6.6**	21.4	**14.9**
4	8.1	7.1	7.6	17.1	3.6	7.5	1.7	19.0	6.3
5+	4.4	3.3	3.7	**19.4**	**1.2**	3.8	0.4	**28.7**	2.8

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