2013 Atlantic Tropical Cyclone Outlook

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Summary of 2013 Forecast Results

The 2013 Atlantic** hurricane season is forecast to be above the long-term average***. Specific forecasts are described below.

1. Expected number of tropical cyclones (tropical storms and hurricanes) developing in the Atlantic Basin: 13-17 (1950-2012 average: 10.8)
2. Expected number of hurricanes developing in the Atlantic basin: 7-10 (1950-2012 average: 6.3)
3. Expected number of major hurricanes developing in the Atlantic basin: 3-6 (1950-2012 average: 2.7)
4. Expected number of tropical cyclones in the Caribbean Sea: 3-6 (1950-2012 average: 2.6)
5. Expected number of hurricanes in the Caribbean Sea: 2-3 (1950-2012 average: 1.4)
6. Expected number of major hurricanes in the Caribbean Sea: 1-2 (1950-2012 average: 0.8)
7. Expected number of tropical cyclones in the Gulf of Mexico: 3-5 (1950-2012 average: 3.1)
8. Expected number of hurricanes in the Gulf of Mexico: 1-2 (1950-2012 average: 1.6)
9. Expected number of major hurricanes in the Gulf of Mexico: 0-1 (1950-2012 average: 0.7)

*Range of expected values was obtained using a 95 percent prediction interval for the number of counts.

**Atlantic hurricane season starts on June 1, and ends on November 30. Atlantic basin includes the Gulf of Mexico and the Caribbean Sea.

***Technical reports can be accessed from: http://cfdl.meas.ncsu.edu/research/TCoutlook_2013.htm

1 Introduction

In this outlook, we aim to forecast the numbers of Tropical Cyclones (TCs), including Tropical Storms (TSs), Hurricanes (HRs), and Major Hurricanes (MHs), that form or pass through particular areas of the Atlantic Basin for the hurricane season (1 June to 30 November) of 2013. The three regions include the Atlantic Ocean basin, and the two sub-regions, the Caribbean Sea and the Gulf of Mexico.

A statistical log-linear regression model was utilized to achieve this goal. In this year's outlook, we expanded the candidate predictors by including more climate indices (18 in total). In addition, a variable selection method was employed to select the relevant predictors from a large set of available candidate predictors. Details regarding the data, model, and results are given in the following sections.

2 Data

The historical TC counts were obtained by manually counting them based on the National Hurricane Center (NHC) HURDAT best track data map available at: http://www.nhc.noaa.gov/pastall.shtml, as well as the Re-Analysis project: http://www.aoml.noaa.gov/hrd/hurdat/DataByYearandStorm.htm.

TC counts are determined by region and then further categorized by the peak intensity within each region according to the Saffir-Simpson hurricane wind scale. The three regions are the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The Atlantic Ocean regions (ATL) stands for the whole Atlantic TC basin, the Caribbean Sea region (CAR) is in enclosed by the West Indies and the coast of Central America from the East coast of the Yucatan Peninsula to Venezuela, and the Gulf of Mexico region (GOM) is bordered by the Gulf Coast of the United States (from the Southern tip of Florida to Texas) to Mexico and the Northern edge of the Yucatan Peninsula and the Northwestern coast of Cuba. This best track data for the Atlantic basin are available since 1851. However, only data after 1950 were used in building the statistical model here because of the large uncertainties in the earlier data. Subtropical and extra-tropical storms, as well as storms outside of the 1 June–31 November hurricane season were filtered out.

Various climate factors were utilized as candidate predictors to assist in the prediction of TC counts for an upcoming hurricane season. These candidate predictors include SST-related climate indices, El Nino–Southern Oscillation (ENSO) related indices, atmospheric and teleconnection indices, as well as parameters in the Main Development Region (MDR) for Atlantic hurricanes.

AMM (Atlantic Meridional Mode): The result of a maximum covariance analysis of SSTs and the zonal and meridional winds over the region 21S–32N, 74W–15E. This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

AMO (Atlantic Multi-decadal Oscillation): An index based on North Atlantic SSTs. This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

TNA (Tropical Northern Atlantic): Anomaly of the average of the monthly SST from 5.5N to 23.5N and 15W to 57.5W. This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

TSA (Tropical Southern Atlantic): Anomaly of the average of the monthly SST from 0-20S and 10E-30W. This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

DM (Atlantic Dipole Mode): The difference between TNA and TSA SSTs.

WHWP (Western Hemisphere Warm Pool): Monthly anomaly of the ocean surface area warmer than 28.5 ℃ in the Atlantic and eastern North Pacific. This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

GGST, NGST, and SGST: Global, north-hemisphere, and south-hemisphere monthly Land-Surface Air and Sea-Surface Water Temperature Anomalies based on the GISS Surface Temperature Analysis (GISTEMP). Data is obtained from http://data.giss.nasa.gov/gistemp/.

NINO12: SST anomalies in the Nino1+2 region. This index is obtained from http://www.cpc.ncep.noaa.gov/data/indices/sstoi.indices. To represent ENSO impacts, NINO12 values for the July/August/September average during the hurricane season were used in building the model. And the forecast values for NINO12 obtained from the National Center for Environmental Protection (NCEP) coupled forecast system (CFS) model were used for forecasts of the upcoming hurricane season from 1 June–31 November 2013.

SOI (Southern Oscillation Index): This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

NAO (Northern Atlantic Oscillation): This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

EPO (East Pacific/North Pacific Oscillation): This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

PNA (Pacific North American Index): This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

AO (Arctic Oscillation): This index is obtained from http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml

QBO (Quasi-Biennial Oscillation): This index is obtained from http://www.esrl.noaa.gov/psd/data/climateindices/list/.

SFI (Solar Flux): observed monthly solar flux (10.7cm) at Ottawa/Penticton. Data available from http://www.ngdc.noaa.gov/nndc/struts/results?op_0=eq&v_0=Penticton_Observed&t=102827&s=4&d=8&d=22&d=9

MDRSLP, MDRSST, MDRVWS: Monthly averaged sea-level pressure (MDRSLP), SST (MDRSST), and vertical wind shear (MDRVWS, wind shear between 200 and 850 mb), over the main development region (MDR, 10-20N, 80-20W). Data derived from the NCEP/NCAR Reanalysis I dataset by http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl.

3 Methods

Our goal is to estimate the expected TS, HR and MH counts (predictands) to form in a particular area, represented by λ_i for i=1,…,9. Forecasts are made for TS, HR and MH counts for each region as listed in Table 1. TS includes tropical storms, hurricanes (categories 1-2), and major hurricanes (categories 3-5); HR includes hurricanes and major hurricanes; MH includes major hurricanes only.

Table 1**.** Predictands including the TS, HR and MH counts for each region during the forecast hurricane season.

Region	Category	Predictand
ATL	TS	λ_1
	HR	λ_2
	MH	λ_3
CAR	TS	λ_4
	HR	λ_5
	MH	λ_6
GOM	TS	λ_7
	HR	λ_8
	MH	λ_9

The statistical model of log-linear regression is used, which assumes the log(λ_i) to be linearly related to the selected climate indices. The January and February values for the indices are chosen based on an analysis of the quality of hindcast predictions using only data up to the hindcasted year. Once the months for each index are selected, the averages of the values are calculated to create a single representative value from each index. Before implementing the regression we apply a variable selection technique to identify the combination of indices that has the best predictive ability for each region and strength category. Many of the indices show correlation to each other, so we use the Lasso methodology which allows for variable selection in the presence of correlation among the predictors. Table 2 shows the selected predictor indices for each category.

Table 2**.** Selected predictor indices for each predictand.

Region	Category	Selected pedictors
ATL	TS	AMM, EPO, MDRSST, MDRVWS, NGST, QPO, SFI, TSA, NINO12
	HR	AMM, AO, EPO, MDRSLP, MDRVWS, NGST, QPO, SFI, SOI,TSA, WHWP, NINO12
	MH	AMO, EPO, MDRSLP, TSA, NINO12
CAR	TS	AMM, AMO, EPO, MDRSLP, MDRVWS, NGST, SFI, TSA, NINO12
	HR	AMM, AMO, EPO, MDRSLP, SFI, TSA, NINO12
	MH	AMO
GOM	TS	AMO, TSA
	HR	
	MH	

An advantageous aspect of the Lasso methodology is that the contribution of each climate index on the predicted counts is easily interpretable compared to dimension reduction techniques such as principle component analysis (PCA). Once the predictors are selected, the log of our response is modeled as

$$\log(\lambda) = \beta_0 + \sum \beta_k \,(Index_k) + \varepsilon,$$

where β_0 is the intercept; β_k and $Index_k$ are the regression coefficients and the selected indices, respectively, which are specific to each region and intensity category; and ε is the random error. Using the data from previous years, the coefficients are estimated using maximum likelihood methods. With these estimates, we then use the current climate index values (listed in Table 3) to predict the values of $\log(\lambda_i)$ for year 2013. All values are normalized based on the 1950 - 2012 values.

Table 3**.** Values of climate indices used in forecast of year 2013

Predictor	Months Averaged Over	Value
AMM	January and February 2013	0.78
AMO	January and February 2013	1.06
AO	January and February 2013	-0.30
EPO	January and February 2013	-0.35
MDRSLP	January and February 2013	-0.03
MDRSST	January and February 2013	0.91
MDRVWS	January and February 2013	-0.32
NGST	January and February 2013	1.02
NINO12*	July, August and September 2013	-0.50
QBO	January and February 2013	-0.10
SFI	January and February 2013	-0.23
SOI	January and February 2013	-0.28
TSA	January and February 2013	0.63
WHWP	January and February 2013	0.09

* Forecast value from NCEP CFS model.

The forecast values for NINO12 are obtained from the National Center for Environmental Protection (NCEP) Coupled Forecast System (CFS) model. We use the ensemble mean for July, August, and September from CFSv2 shown in Figure 1, which is -0.5.

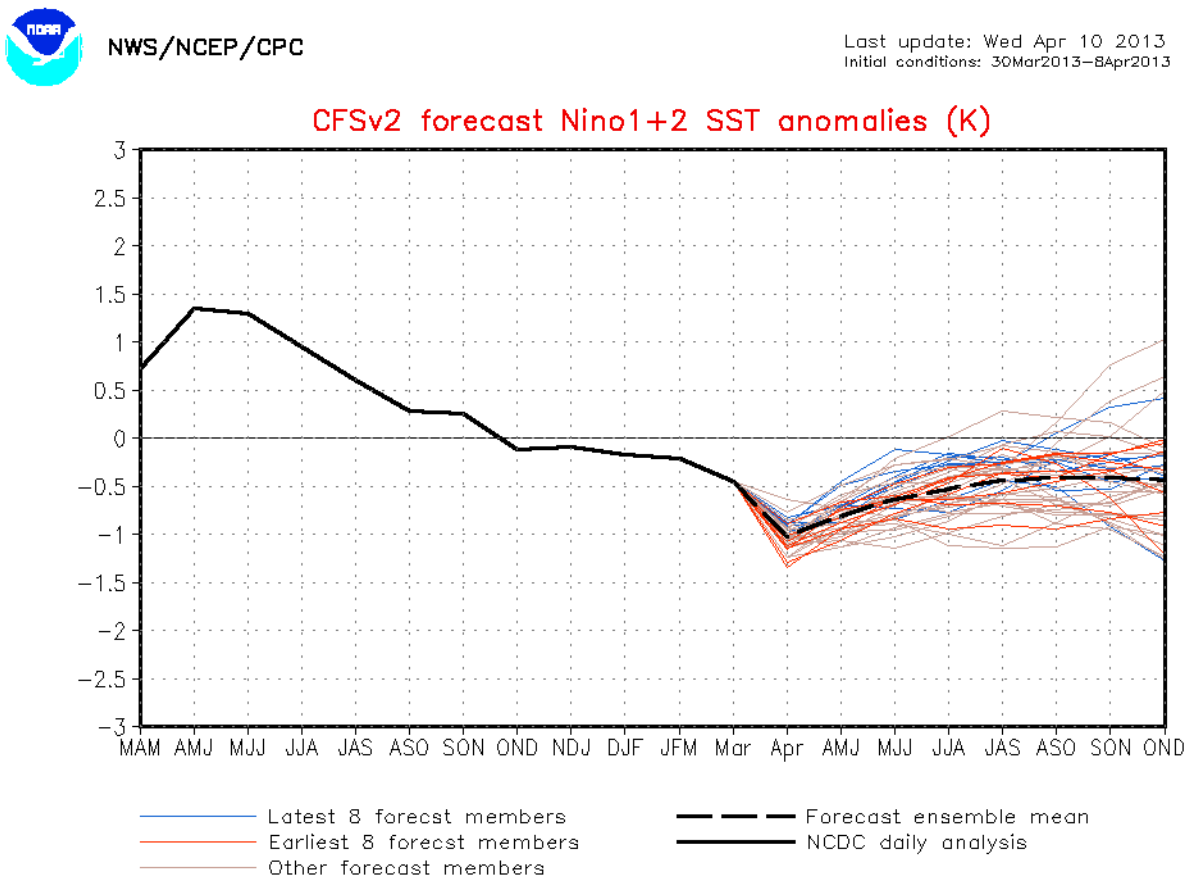

Figure 1. NINO12 forecasts from NCEP CFSv2 model
http://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

4 Model validation

We have conducted hindcast (re-forecast) analyses to evaluate the predictive ability of our models. Figures 2-4 show the predicted TC counts for each region and intensity category during the years 2000 through 2012 using only the data up to the previous year. The same set of predictors selected by Lasso for the entire dataset are used, and the coefficients are determined using the same methodology as described in Section 3, but using only those predictors and the data up to the year before the predicted year. So, for example, the prediction for the year 2000 uses only the data up to year 1999 to determine the coefficients. The models for the Gulf of Mexico have relatively the least predictive skill, the models for the Caribbean Sea have intermediate predictive skill, and the models for the North Atlantic basin have the best predictive skill.

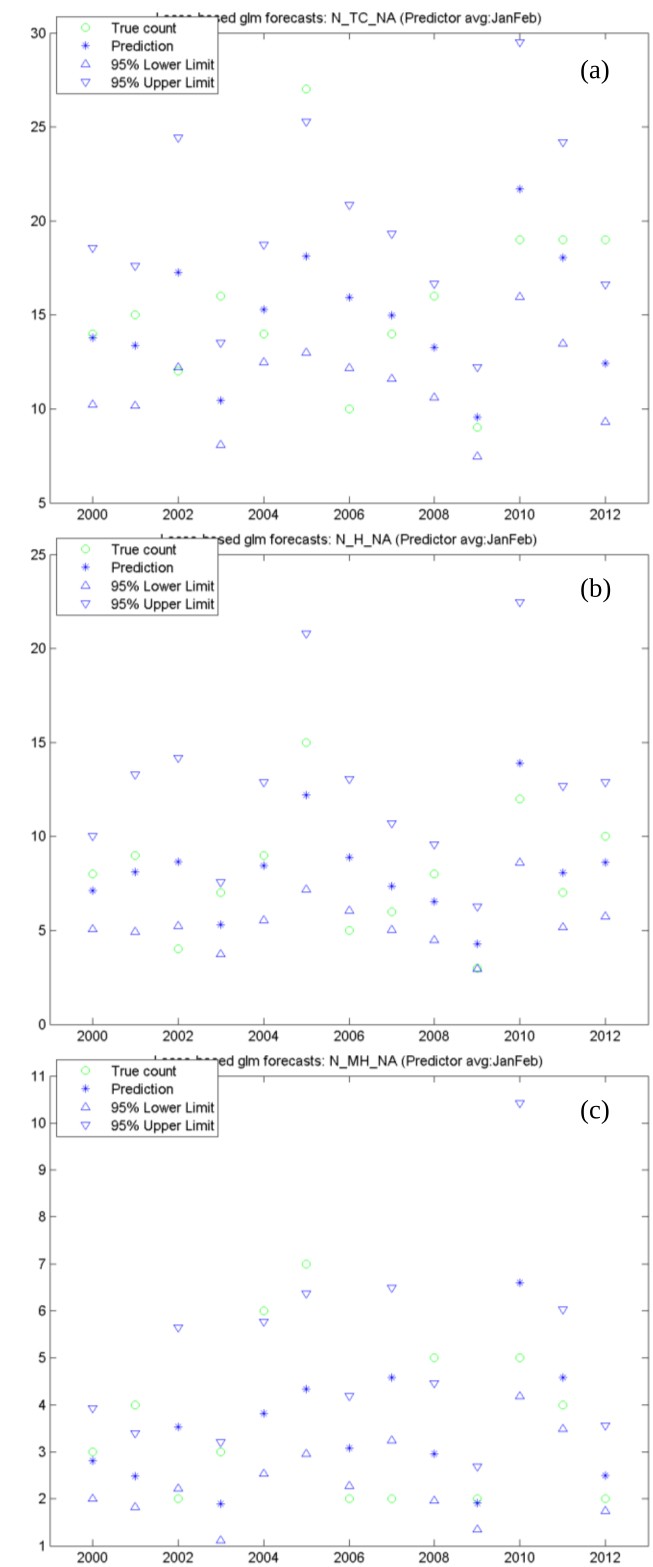

Figure 2. Hindcast results for (a) TS, (b) HR, and (c) MH counts from 2000 to 2012 in the Atlantic basin.

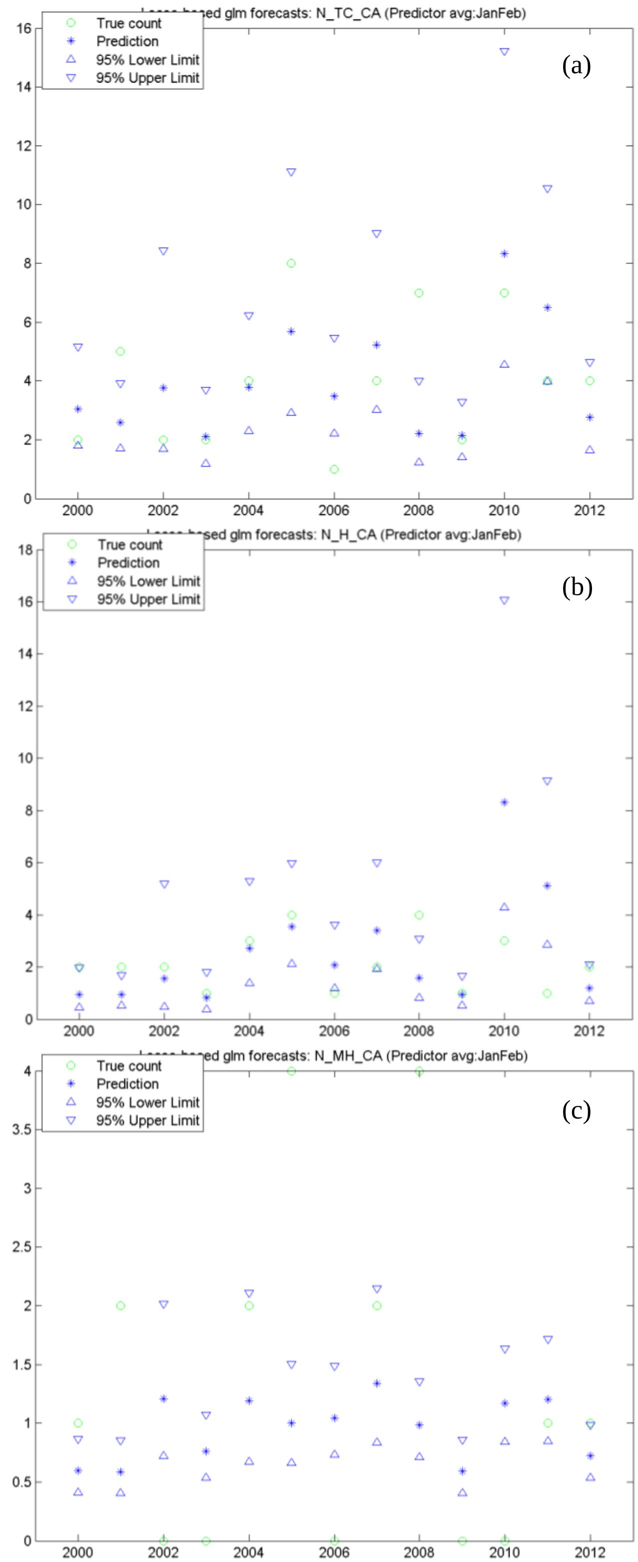

Figure 3. Hindcast results for (a) TS, (b) HR, and (c) MH counts from 2000 to 2012 in the Caribbean Sea.

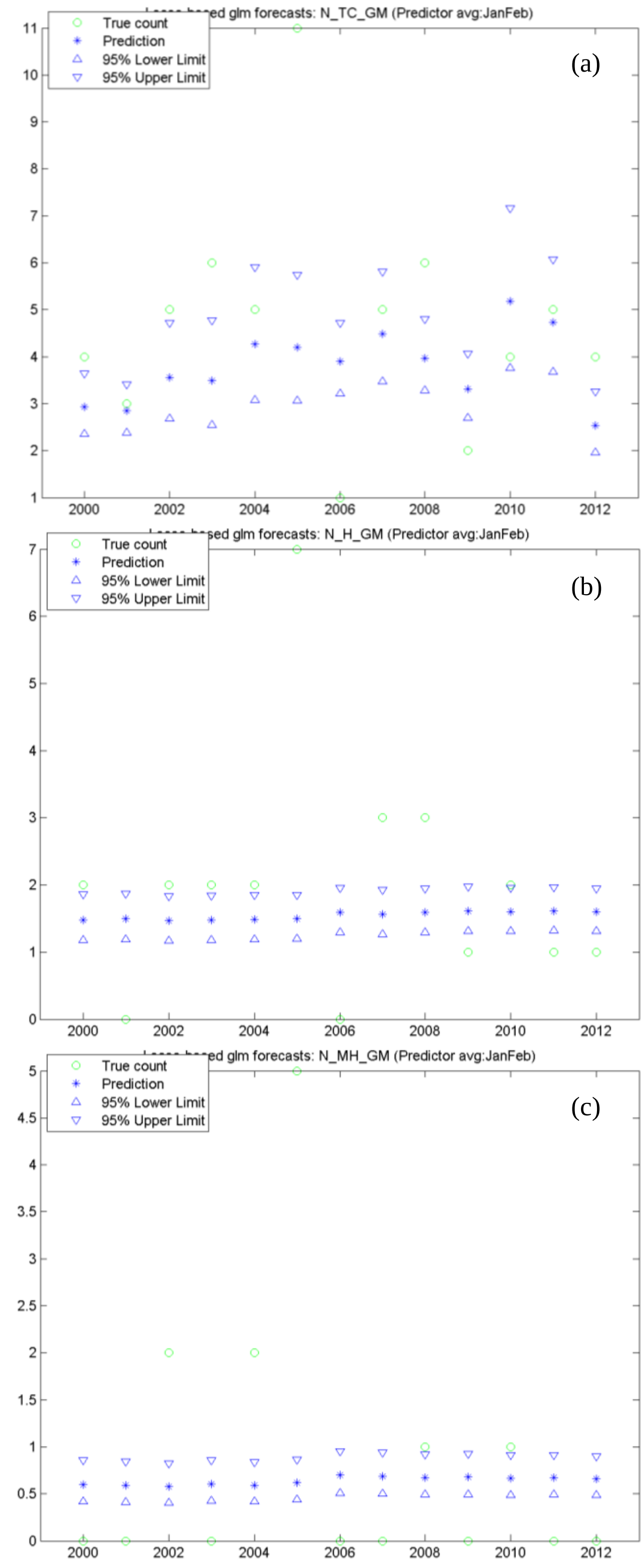

Figure 4. Hindcast results for (a) TS, (b) HR, and (c) MH counts from 2000 to 2012 in the Gulf of Mexico.

5 Results for 2013

The values of λ are calculated using the methodology described in Section 3. Using the normal approximation, we also create 95% prediction intervals for the log(λ_i). We transform back to the scale of the data by exponentiating the estimates and bounds. This does result in non-symmetric prediction limits, but is still a 95% interval since the exponential function is monotone. The estimated number of storms (λ_i) and the lower and upper bounds are listed in Table 4.

Table 4**.** Estimates and 95% prediction intervals for the expected TC counts for each region and intensity category.

Region	Category	Forecasts for year 2013		
		Lower Limit	Estimate	Upper Limit
ATL	TS	13.5	15.2	17.1
	HR	7.1	8.5	10.0
	MH	3.3	4.2	5.3
CAR	TS	3.2	4.1	5.3
	HR	1.7	2.3	3.2
	MH	0.8	1.2	1.7
GOM	TS	3.5	4.3	5.2
	HR	1.3	1.6	1.9
	MH	0.5	0.7	0.9

Since the index value for NINO12 was obtained from the forecasts from NCEP CFSv2 seasonal model runs, the TC count predictions can be sensitive to the value of NINO12. To evaluate the sensitivity of the predicted TC counts to the forecasted NINO12 value, we calculate the predicted TC counts using a spread of +0.5 to -0.5 around the forecast ensemble mean.

The count estimate in the '0' column in Table 5 corresponds to the TC count forecast at the forecasted NINO12 value. The range indicates the difference between the predicted counts at the high (forecast +0.5) and low end (forecast -0.5) of the investigated NINO12 spread. The estimated regression coefficients for the NINO12 predictor are negative in all models containing the NINO12 index as a predictor, so higher NINO12 values reduce the predicted counts. The models for major hurricanes in the Caribbean Sea and for all intensity categories in the Gulf of Mexico do not have the NINO12 index selected and are hence not sensitive to deviations in the forecast. One can see that the TC count forecasts are not very sensitive to the NINO12 predictor, with the largest forecast TC count range being only 1.6.

Table 5**.** Sensitivity to Nino12 forecasts: estimates based on deviations from NINO12 forecast

Region	Category	Forecasts with variable NINO12 index			Forecast TC count range
		+ 0.5	0	-0.5	
ATL	TS	14.4	15.2	16.0	1.6
	HR	7.8	8.5	9.2	1.4
	MH	3.9	4.2	4.5	0.6
CAR	TS	3.6	4.1	4.8	1.2
	HR	2.1	2.3	2.6	0.5
	MH	1.2	1.2	1.2	0.0
GOM	TS	4.3	4.3	4.3	0.0
	HR	1.6	1.6	1.6	0.0
	MH	0.7	0.7	0.7	0.0

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