2012 Atlantic Tropical Cyclone Outlook

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Summary of 2012 Forecast Results

The 2012 Atlantic** hurricane season is forecast to be on par with the long-term average***. Specific forecasts are described below.

1. Expected number of tropical cyclones (tropical storms and hurricanes) developing in the Atlantic Basin: 7-10 (1950-2012 average: 10.5)
2. Expected number of hurricanes developing in the Atlantic basin: 4-7 (1950-2012 average: 6.2)
3. Expected number of major hurricanes developing in the Atlantic basin: 1-3 (1950-2012 average: 2.7)
4. Expected number of tropical cyclones in the Gulf of Mexico: 2-4
5. Expected number of hurricanes in the Gulf of Mexico: 1-2
6. Expected number of major hurricanes in the Gulf of Mexico: 0-1
7. Number of tropical cyclones making landfall along the US Gulf coast: 1-3. There is a 84% chance at least one tropical cyclone will strike the US Gulf Coast, which reduces to 51% for a hurricane and 24% for a major hurricane.
8. There is a 58% chance at least one tropical cyclone will strike the US Southeast coast. This probability reduces to about 35% for a hurricane, and approximately 13% for a major hurricane.
9. There is a 32% chance at least one tropical cyclone will make landfall along the US Northeast coast. The chance reduces to about 13% for that storm to be a hurricane. The chance for a major hurricane to make landfall in the Northeast US coast is historically small, and is essentially unpredictable due to insufficient data sample.

*Range of expected values 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. Northeast coast extends from Virginia to Maine. Southeast coast covers the coastal region of the east coast of Florida to North Carolina.
***Technical reports can be accessed from:
http://cfdl.meas.ncsu.edu/research/TCoutlook_2012.htm

1 Data

We forecast the number of storms that either form in a particular area of the Atlantic Basin or make landfall to a particular area of the US coastline. Information to obtain these counts is available from the Tropical Prediction Center Best Track Reanalysis at http://weather.unisys.com/hurricane/atlantic/index.html. This site lists tropical systems in the Atlantic since 1851. To train our model we use past storm counts from 1950 to 2010. We utilize various weather indices to assist in the prediction of the counts for an upcoming hurricane season. We obtain these monthly indices from http://www.cdc.noaa.gov/data/climateindices/ and include Atlantic Meridional Mode (AMM), Atlantic Multidecadal Oscillation (AMO), Atlantic Warm Pool (AWP), Dipole Mode (DM), Tropical Northern Atlantic (TNA), Tropical Southern Atlantic (TSA), Western Hemisphere Warm Pool (WHWP), and a representation of El Niño-Southern Oscillation (ENSO). AMM is calculated from sea surface temperature (SST) datasets over the region between 21S to 32N and 74W to 15E. AMO is a time series calculated from the Kaplan SST dataset that is an index on North Atlantic temperatures. This detrended time series is a weighted average of SSTs between latitudes 0 and 70N. The AWP is a weighted average of SSTs between latitudes 6 and 30N and longitudes 10 and 100W. DM is the difference in average SST over two locations in the Atlantic. Box 1 is the area within latitude 4 to 24N and longitude 16 to 60W. Box 2 is the area within latitude 4 to 24S and longitude 30W to 12E. TNA is the anomaly of the average of the monthly SST from 5.5N to 23.5N and 15W to 57.5W. TSA is the anomaly of the average of the monthly SST from Equator to 20S and 10E to 30W. The WHWP is the monthly anomaly of the ocean surface area warmer than 28.5C in the Atlantic and eastern North Pacific. To represent ENSO we use the anomalies for regions one and two, referenced NINO12. For estimating the upcoming number of storms we use the forecasted NINO12 values for the upcoming hurricane season from June 1st to November 30th, 2012.

2 Methods

Our goal is to estimate the expected number of tropical cyclones (TC), hurricanes (H) and major hurricanes (MH) to form or make landfall in a particular area, represented by λ_i for i=1,…,18. Forecasts are made for TC, H, and MH counts and landfalls as listed in table 1. TC includes tropical storms, hurricanes (categories 1-2), and major hurricanes (categories 3-5); H includes hurricanes and major hurricanes; MH includes major hurricanes.

Table 1: *2012 Forecast Regions*

Storm Counts	Landfalls
Gulf of Mexico basin	Gulf coast
Caribbean basin	Southeast coast[2]
Atlantic basin[1]	Northeast coast[3]

[1] The Atlantic, Gulf of Mexico and the Caribbean
[2] East coast of Florida to the North Carolina/Virginia border
[3] North Carolina/Virginia border through Maine

We use the statistical model of log-linear regression, which assumes the log(λ_i) to be linearly related to the selected climate indices. We chose which months to include for the indices following research of Elinor Keith. 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 examine the correlations between the climate indices. All values, except TSA and NINO12, show strong correlation to each other. To alleviate this issue, we perform a principle component analysis (PCA) on the remaining indices. A PCA takes many correlated values and reduces them into fewer uncorrelated values. These values are organized by the amount of variability explained in the data. We incorporate the first principle component (PC1), TSA, and NINO12 into our regression equation. The log of our response is modeled as

$$\log(\lambda) = \beta_0 + \beta_1(PC1) + \beta_2\,(TSA) + \beta_3(NINO12) + \varepsilon,$$

where β_0 is the intercept; β_1, β_2, and β_3 are the regression coefficients; and ε is the random error. Using the data from previous years, the coefficients for PC1, TSA, and NINO12 are estimated using maximum likelihood methods. With these estimates, we then use the current climate index values (listed in table 2) to predict the values of log(λ_i).

The forecast values for NINO12 are obtained from the National Centers for Environmental Protection (NCEP) coupled forecast system (CFS) model as seen in figure 1. We use the ensemble mean from CFSv2 in figure 1 (b). The count predictions can be sensitive to the value of NINO12. In the appendix we examine how the forecasts may be affected.

Table 2: *Values of climate indices used in forecast*

Index Name	Months Averaged Over	Index Value
AMM	January 2012, February 2012, March 2012	0.760
AMO	January 2012, February 2012	0.003
DM	January 2012, February 2012, March 2012	0.676
NAO	January 2012, February 2012, March 20112	0.953
NINO12*	July 2012, August 2012, September 2012	0.910
TNA	January 2012, February 2012	-0.015
TSA	November 2011, December 2011, January 2012	-0.353
WHWP	August 2011, September 2011, October 2011, November 2011	2.068

* Forecast

3. Results

Once the values of λ have been calculated using the methodology of section 2, we compare our forecasts with climatology as seen in figured 2-10 (in gold). We use three climatology values: 1950-2010 (>50 year average), 1991-2010 (20 year average), and 1996-2010 (15 year average). 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. Significant differences between climatology and the forecast values are validated through the 95 percent prediction intervals. If a climatology value falls within this interval, we say that the forecast is not significantly different from the climatology. Estimates based on climatology are listed in table 5.

Figures 2-10 show the count probabilities for number of storms and landfalls in the various regions listed in table 1.

Table 4: *Estimates and 95% prediction intervals for the expected number of tropical cyclones in the Atlantic using the model of section 2.*

Category		Lower Limit	Estimate	Upper Limit
Gulf Coast Landfalls	Tropical Cyclone	1.37	1.85	2.51
	Hurricane	0.44	0.71	1.13
	Major Hurricane	0.12	0.27	0.58
Southeast Landfalls	Tropical Cyclone	0.53	0.82	1.25
	Hurricane	0.20	0.38	0.72
	Major Hurricane	0.05	0.13	0.37
Northeast Landfalls	Tropical Cyclone	0.21	0.38	0.68
	Hurricane	0.06	0.14	0.36
	Major Hurricane	0.00	0.00	0.32
Atlantic Storms	Tropical Cyclone	7.63	8.80	10.15
	Hurricane	4.47	5.37	6.46
	Major Hurricane	1.68	2.24	2.99
Caribbean Storms	Tropical Cyclone	1.32	1.81	2.49
	Hurricane	0.63	0.97	1.51
	Major Hurricane	0.29	0.52	0.93
Gulf of Mexico Storms	Tropical Cyclone	2.03	2.63	3.41
	Hurricane	0.83	1.20	1.75
	Major Hurricane	0.28	0.50	0.92

Table 5: *Estimates based on climatology*

Category		>50 year	20 year	15 year
Gulf Coast Landfalls	Tropical Cyclone	2.13	**2.75**	**3.07**
	Hurricane	0.94	1.05	**1.20**
	Major Hurricane	0.39	0.45	0.47
Southeast Landfalls	Tropical Cyclone	1.03	**1.35**	**1.53**
	Hurricane	0.63	**0.75**	**0.80**
	Major Hurricane	0.23	0.20	0.13
Northeast Landfalls	Tropical Cyclone	0.39	0.30	0.27
	Hurricane	0.15	0.05	**0.00**
	Major Hurricane	0.05	0.00	0.00
Atlantic Storms	Tropical Cyclone	**10.52**	**12.90**	**14.00**
	Hurricane	6.18	**7.05**	**7.67**
	Major Hurricane	2.73	**3.25**	**3.73**
Caribbean Storms	Tropical Cyclone	2.42	**3.20**	**3.67**
	Hurricane	1.34	**1.90**	**2.40**
	Major Hurricane	0.76	0.90	**1.13**
Gulf of Mexico Storms	Tropical Cyclone	3.13	**3.80**	**4.27**
	Hurricane	1.61	**1.80**	**2.00**
	Major Hurricane	0.66	0.70	0.80

*Estimates in boldface fall outside the 95% confidence intervals for the expected number of storms in 2012 in table 4.

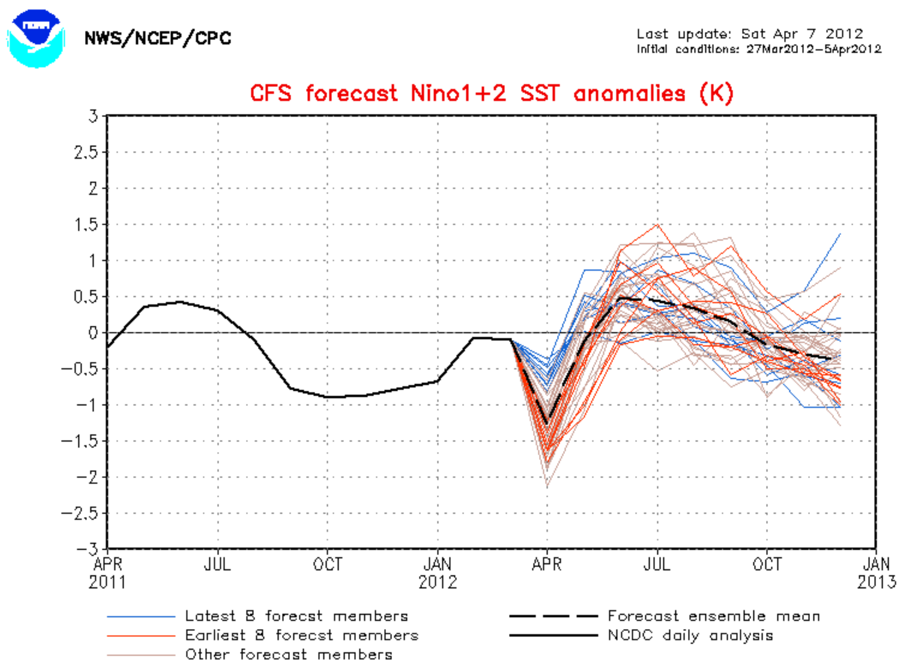


Figure 1 (a): *NINO12 forecasts from NCEP CFS model*[1]

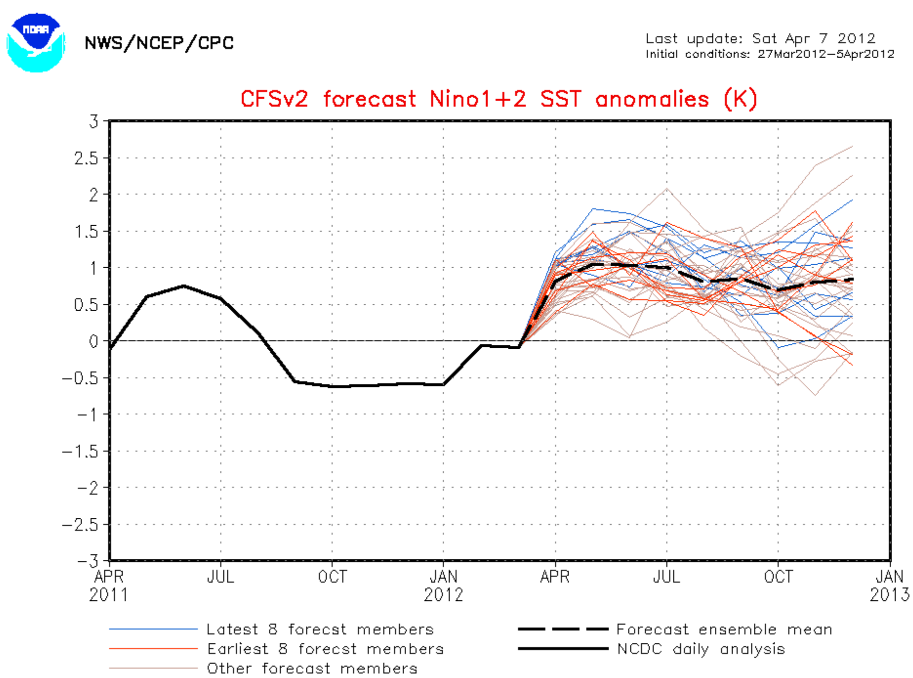


Figure 1 (b) *NINO12 forecasts from NCEP CFSv2 model*[2]

[1] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/ensoforecast.shtml

[2] http://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

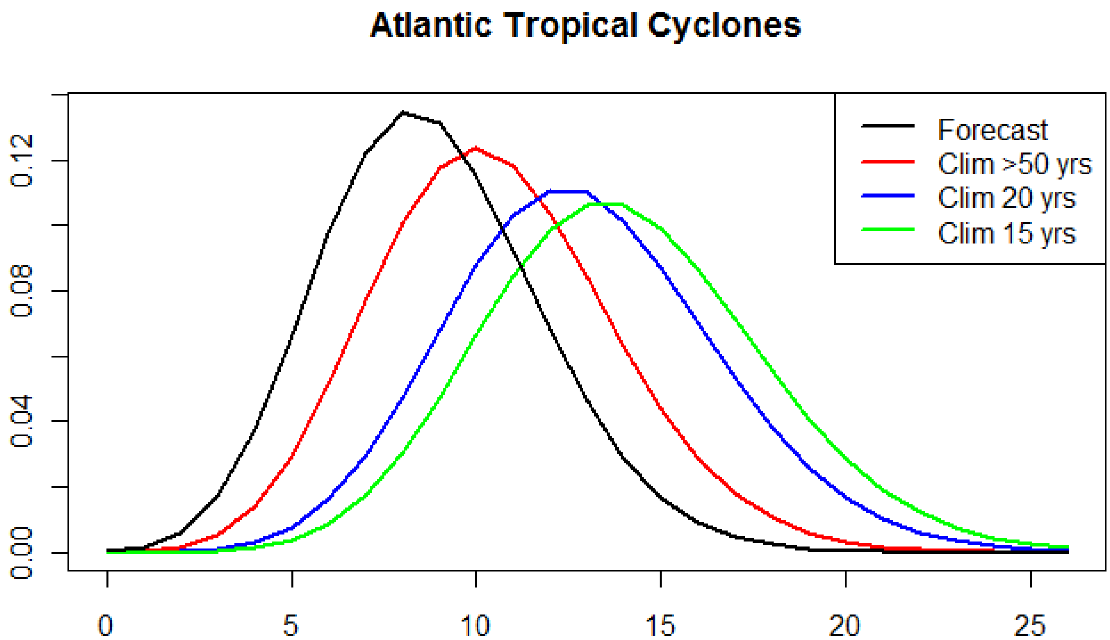


Figure 2: *Probabilities for the number of tropical cyclones in the Atlantic basin for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

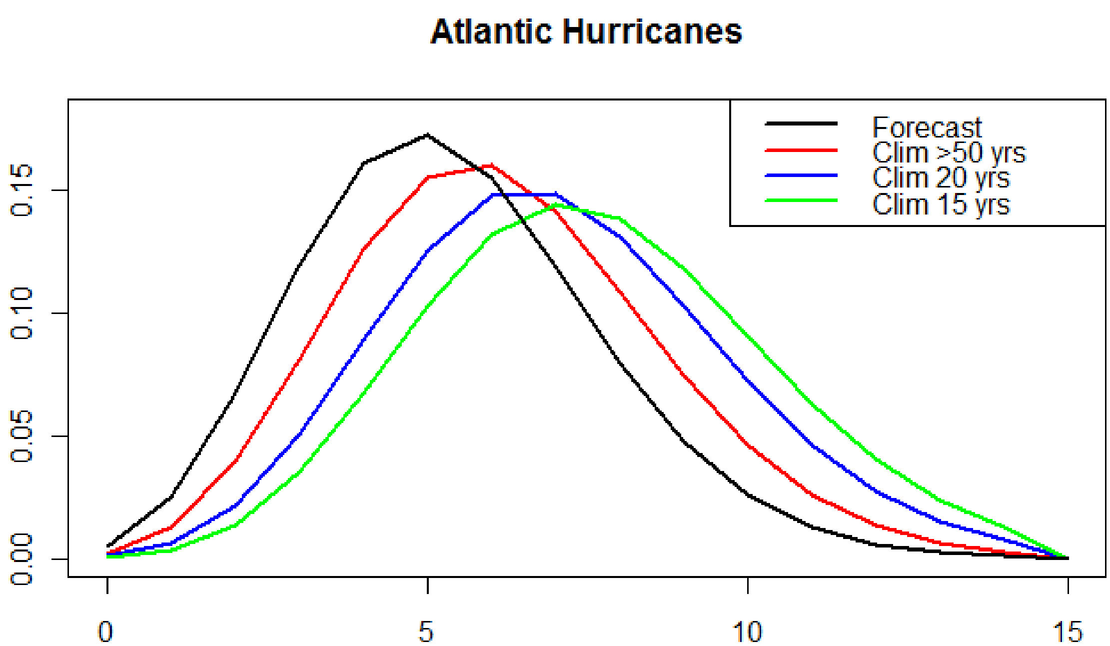


Figure 3: *Probabilities for the number of hurricanes in the Atlantic basin for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

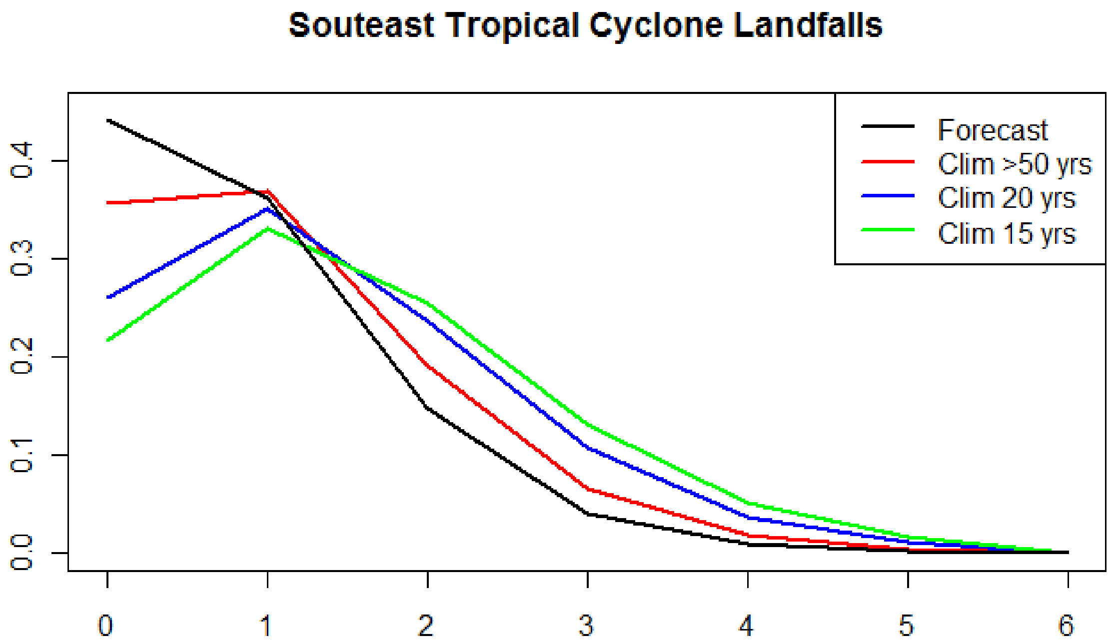


Figure 4: *Probabilities for the number of tropical cyclones landfalls on the southeast coast for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

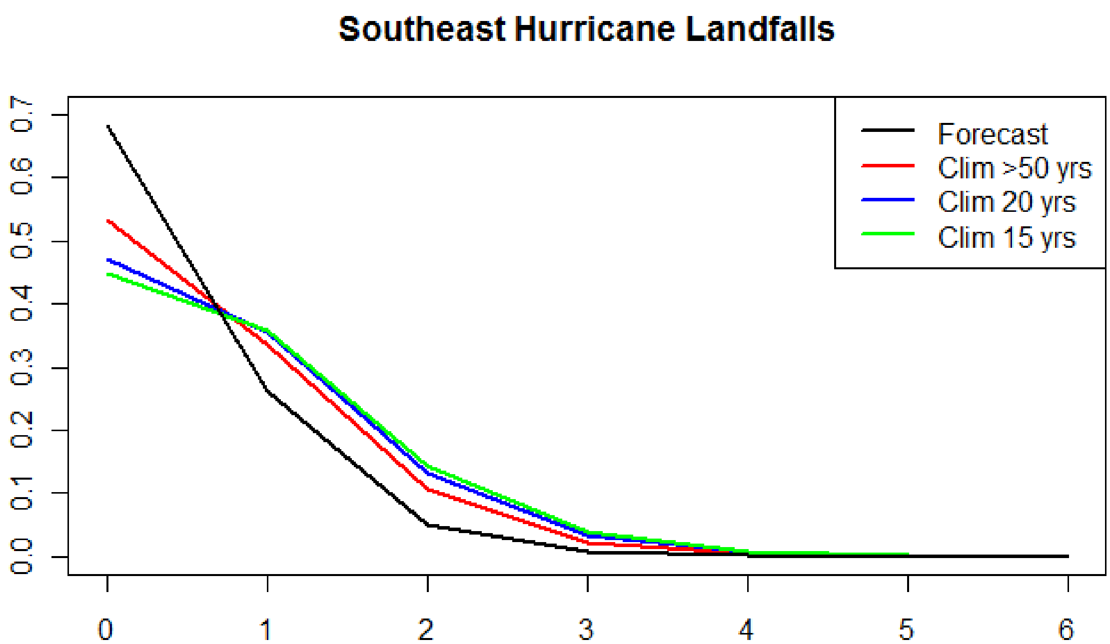


Figure 5: *Probabilities for the number of hurricane landfalls on the southeast coast for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

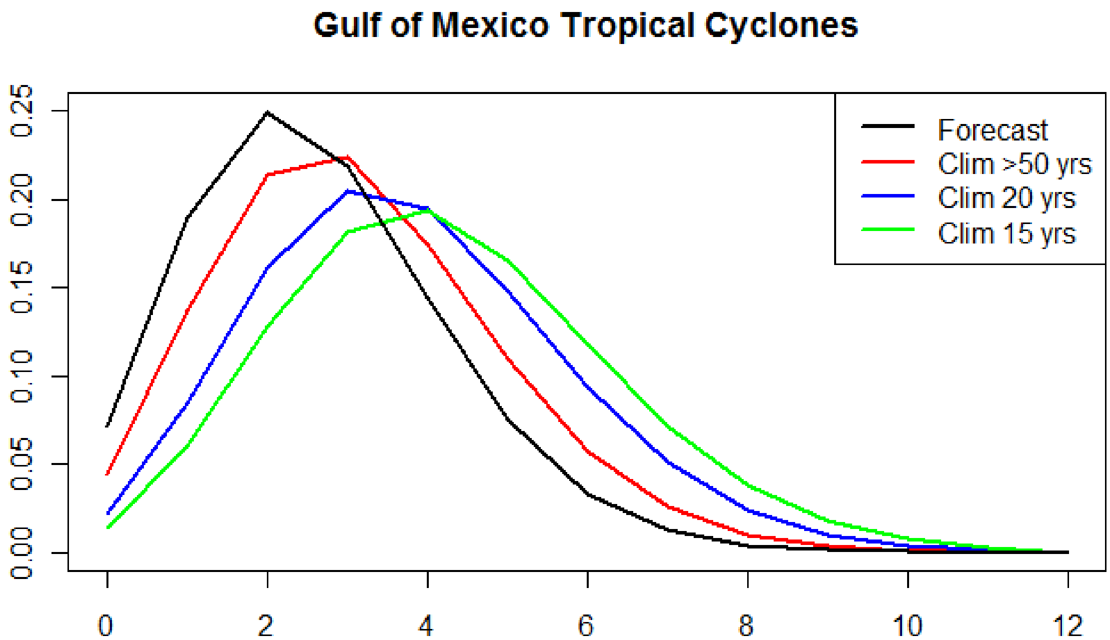


Figure 6: *Probabilities for the number of tropical cyclones in the Gulf Mexico for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

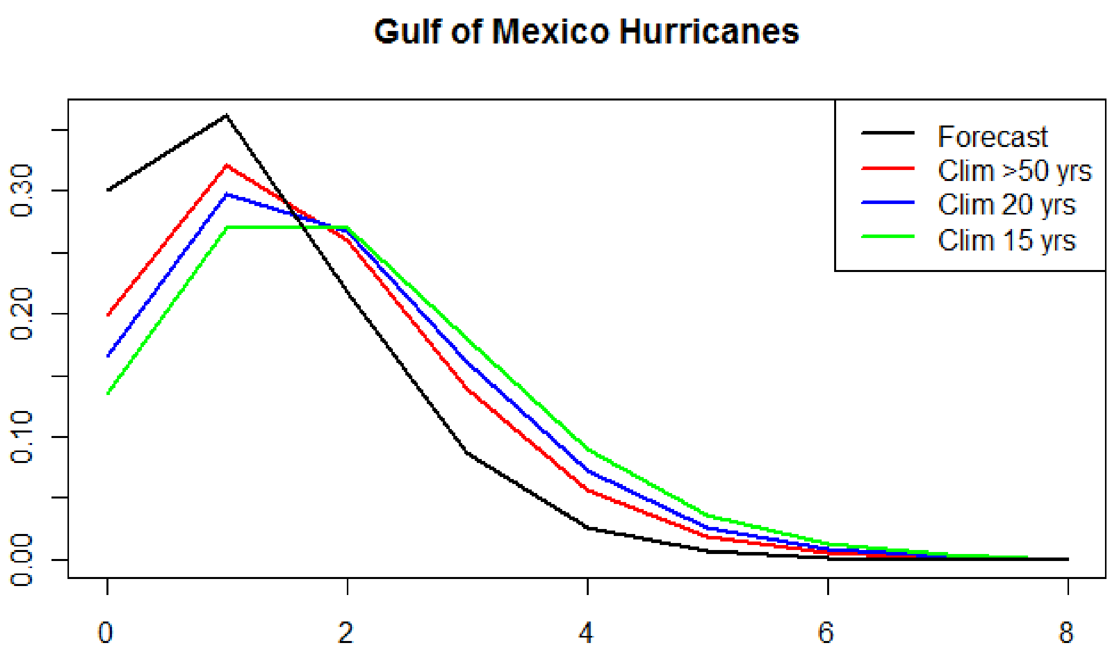


Figure 7: *Probabilities for the number of hurricanes in the Gulf Mexico for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

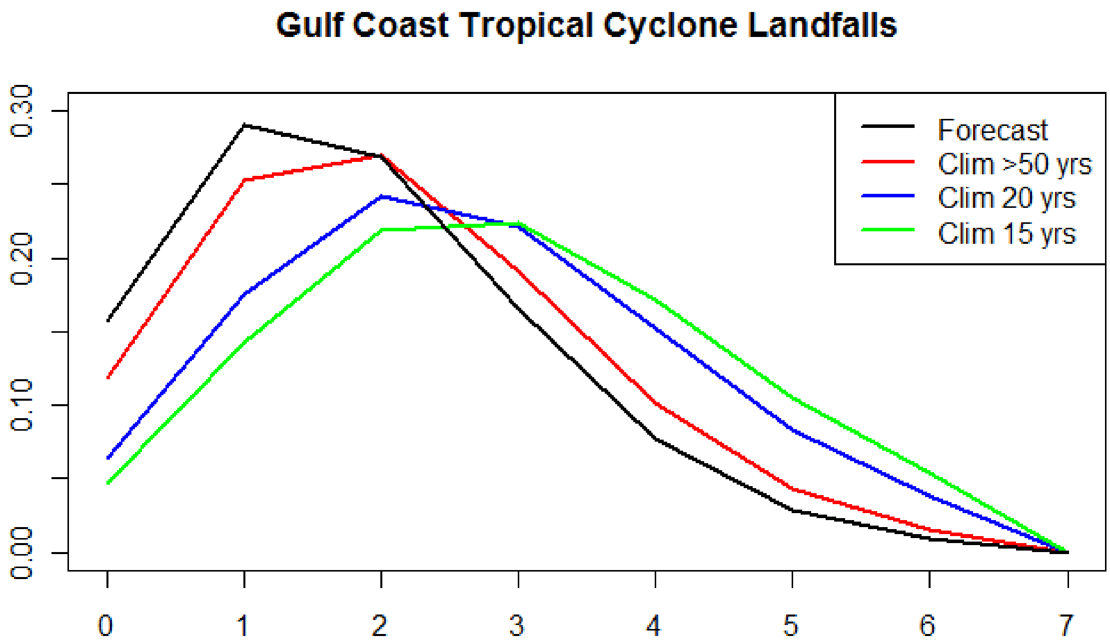


Figure 8: *Probabilities for the number tropical cyclone landfalls on the Gulf coast for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

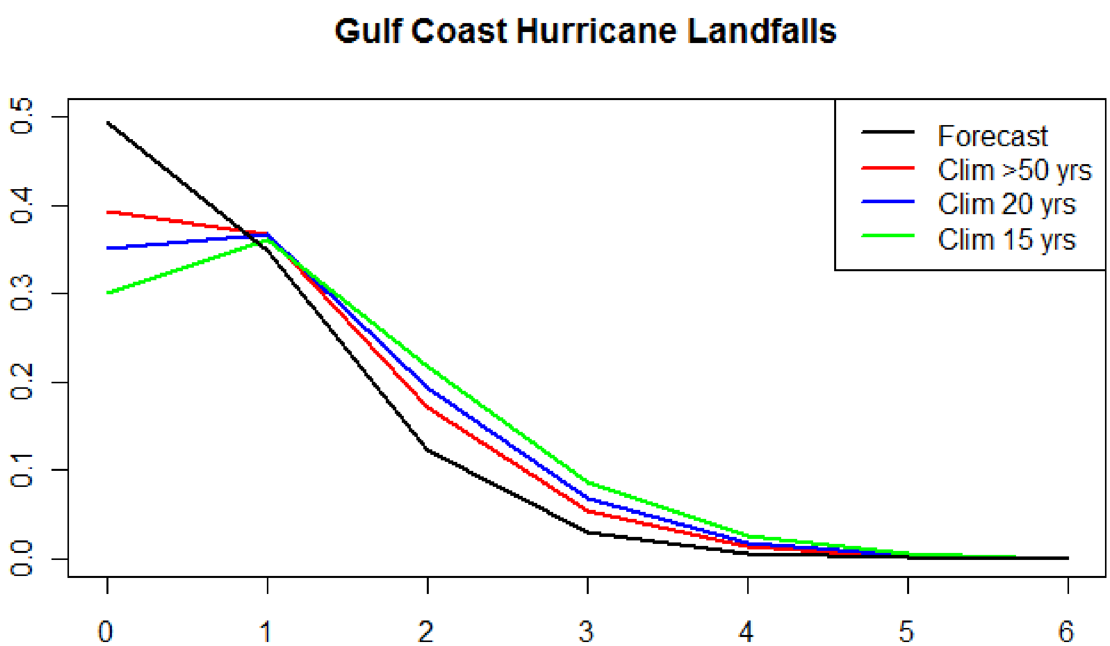


Figure 9: *Probabilities for the number hurricane landfalls on the Gulf coast for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

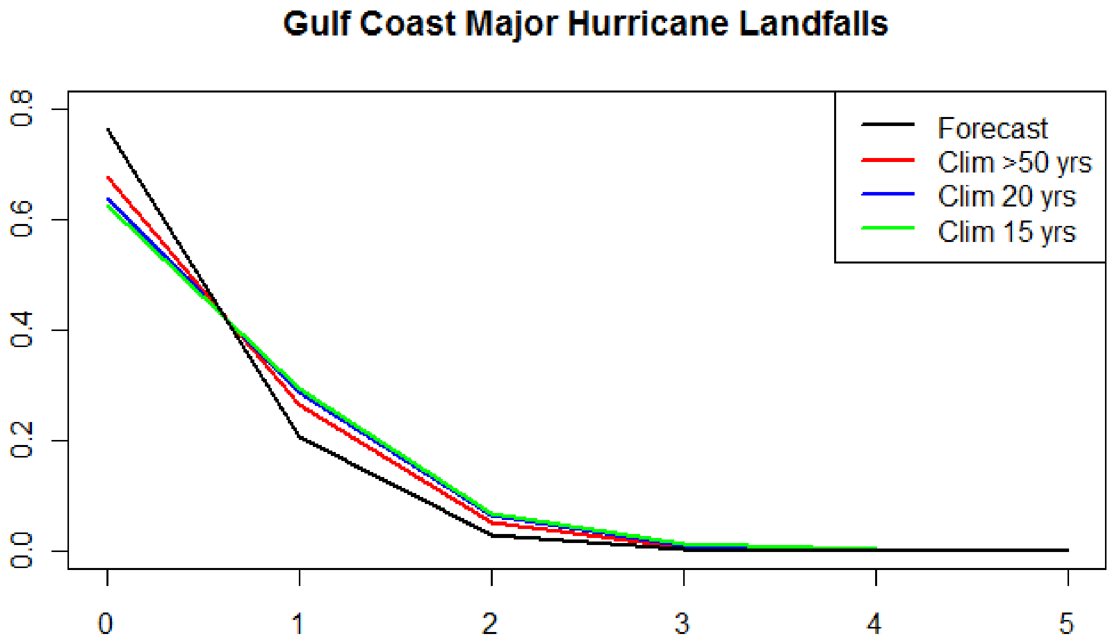


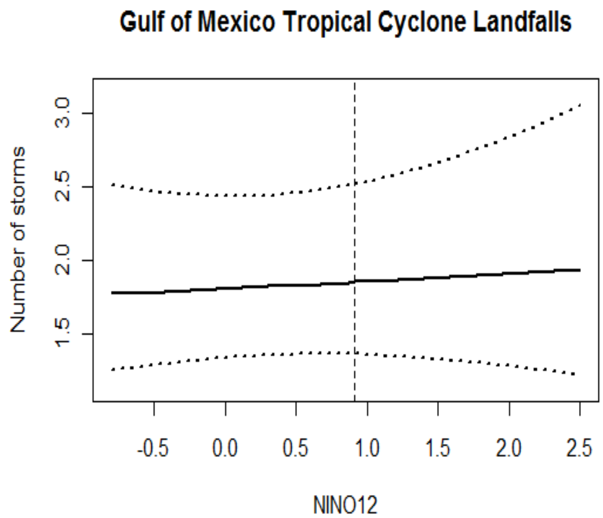
Figure 10: *Probabilities for the number major hurricane landfalls on the Gulf coast for 2012: forecast (black), past 50 years climatology (red), past 20 years climatology (blue) and past 15 years climatology (green).*

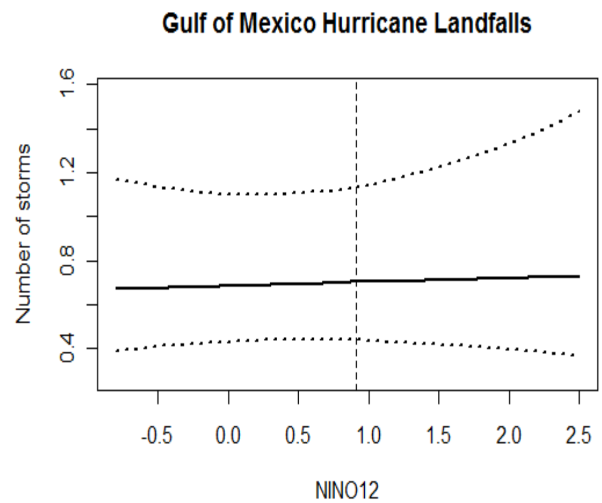
Appendix

Figure 1 shows that there is a range of possible forecast values for NINO12. Here we show how the forecast is affected by changing the forecast value of NINO12. The solid line represents the expected number of storms (y-axis) given a particular value for NINO12 (x-axis). The dotted lines represent the bounds for the 95% interval. The vertical dashed line is at the ensemble mean value for NINO12 used to obtain the results in section 3.

Figure A.1 and figure A.3 show that number of landfalls on the Gulf Coast and the Northeast Coast do not appear to be affected by the NINO12 value. For Southeast Coast, however, we see a decrease in the number of storms that make landfall as values of NINO12 increase (figure A.2).

We observe the same decreasing trend for the overall storm counts in the Atlantic in figure A.4. The sub regions of the Caribbean (figure A.5) and the Gulf of Mexico (figure A.6) also show a decrease in the number of storms as NINO12 increases, although it is minimal in the Gulf.





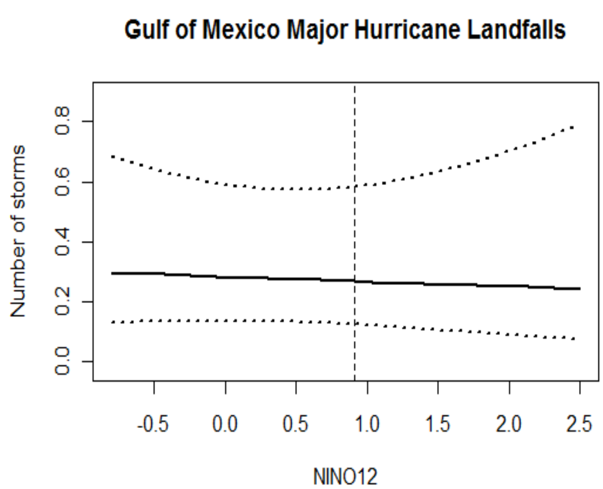
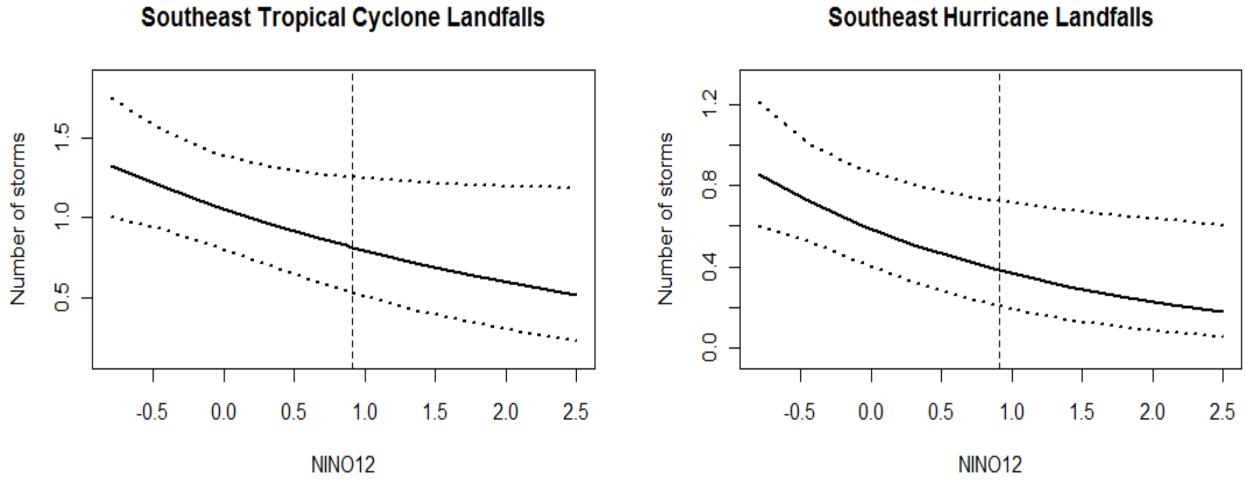


Figure A.1: *The solid line represents the expected number of tropical cyclone, hurricane, and major hurricane landfalls forecast for the Gulf Coast for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*



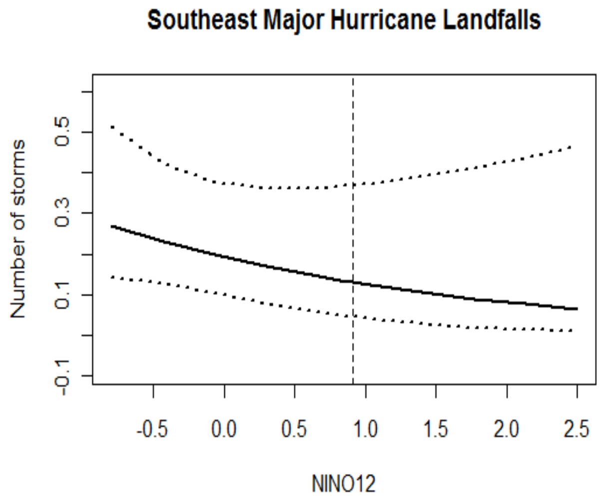
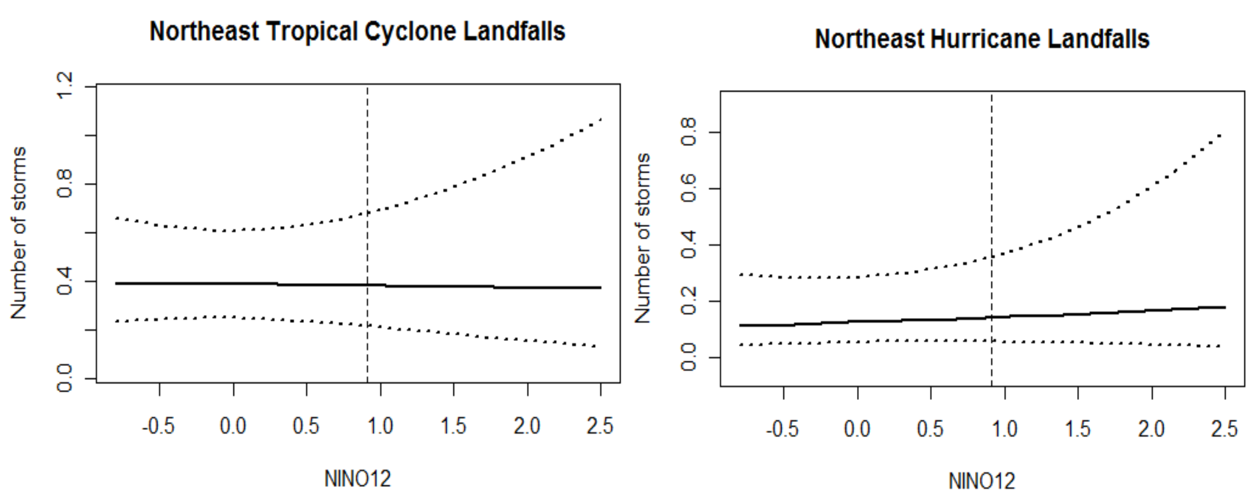
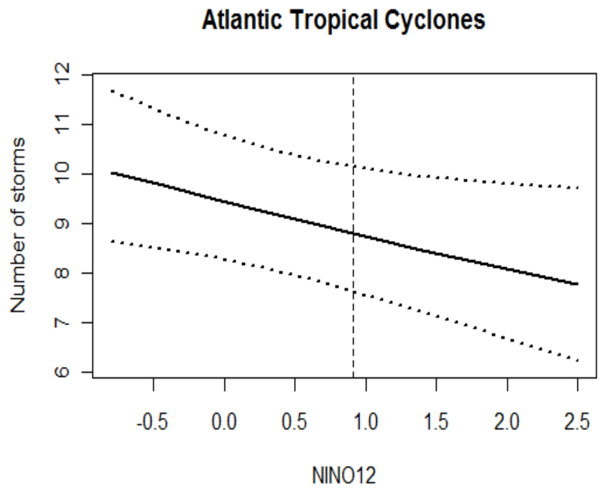
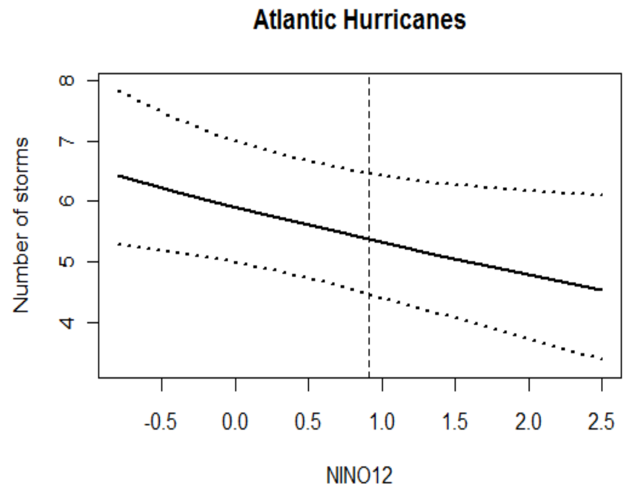


Figure A.2: *The solid line represents the expected number of tropical cyclone, hurricane, and major hurricane landfalls forecast for the Southeast Coast for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*

Figure A.3 (below): *The solid line represents the expected number of tropical cyclone and hurricane landfalls forecast for the Northeast Coast for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*







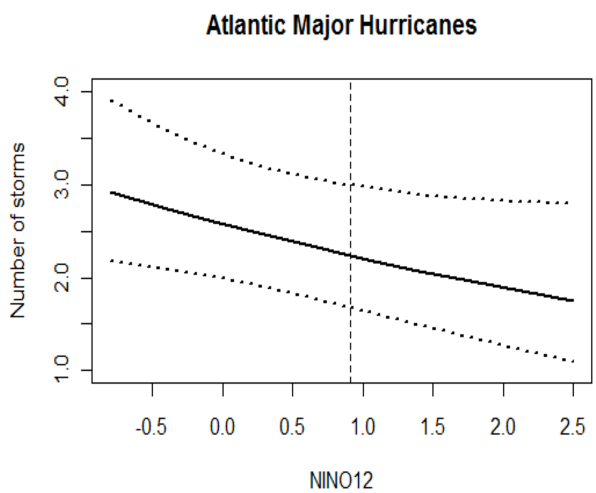
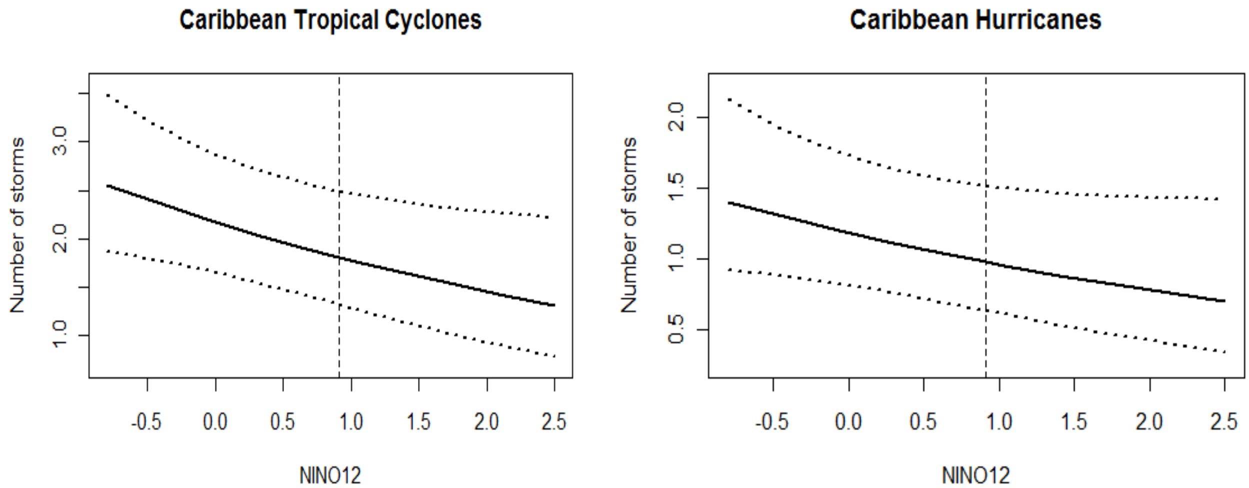


Figure A.4: *The solid line represents the expected number of tropical cyclone, hurricane, and major hurricane counts forecast for the Atlantic Basin for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*



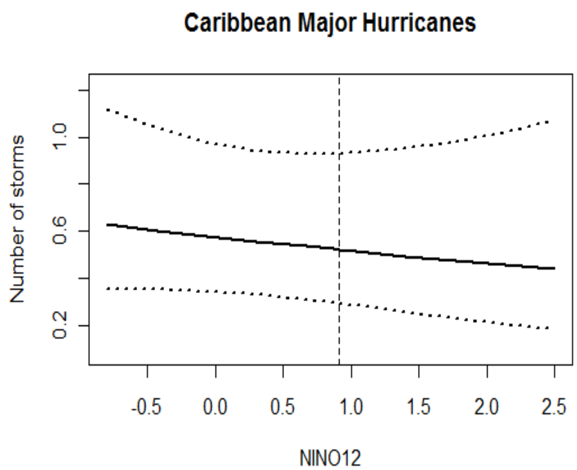
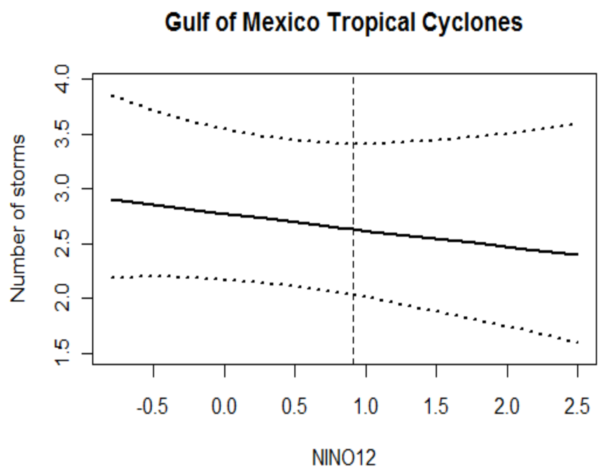
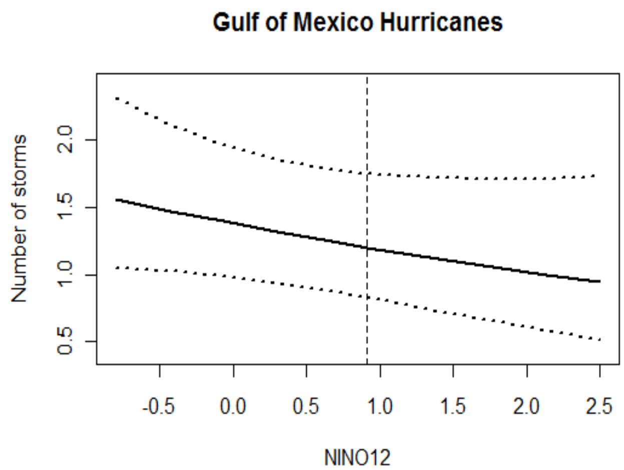


Figure A.5: *The solid line represents the expected number of tropical cyclone, hurricane, and major hurricane counts forecast for the Caribbean for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*





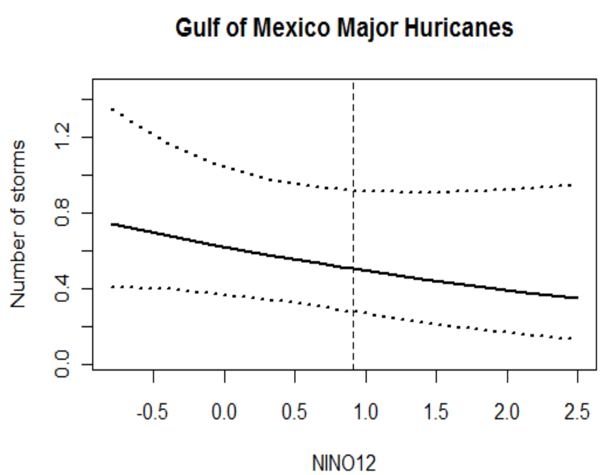


Figure A.6: *The solid line represents the expected number of tropical cyclone, hurricane, and major hurricane counts forecast for the Gulf of Mexico for different values of NINO12. The dotted lines represent the corresponding 95% prediction bounds. The vertical dashed line is at the current ensemble mean for NINO12 used in section 2.*