FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2012

We anticipate a slightly-below average remainder of the hurricane season this year due to an anticipated weak El Niño event and a tropical Atlantic that is less favorable than in the past two years. This forecast is a slight increase from activity predicted in early June, due to a slower-than-anticipated onset of El Niño and a somewhat more favorable tropical Atlantic than observed earlier this year. We expect a slightly below-average probability of United States and Caribbean major hurricane landfall.

(as of 3 August 2012)

By Philip J. Klotzbach[1] and William M. Gray[2]

This forecast as well as past forecasts and verifications are available via the World Wide Web at http://hurricane.atmos.colostate.edu/Forecasts

Emily Wilmsen, Colorado State University Media Representative, (970-491-6432) is available to answer various questions about this forecast

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"It's tough to make predictions, especially about the future". Yogi Berra

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ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2012

Forecast Parameter and 1981-2010 Median (in parentheses)	Issue Date 4 April 2012	Issue Date 1 June 2012	Observed Activity Through July 2012	Forecast Activity After 31 July	Total Seasonal Forecast
Named Storms (NS) (12.0)	10	13	4	10	14
Named Storm Days (NSD) (60.1)	40	50	14.75	37.25	52
Hurricanes (H) (6.5)	4	5	1	5	6
Hurricane Days (HD) (21.3)	16	18	0.75	19.25	20
Major Hurricanes (MH) (2.0)	2	2	0	2	2
Major Hurricane Days (MHD) (3.9)	3	4	0	5	5
Accumulated Cyclone Energy (ACE) (92)	70	80	14	85	99
Net Tropical Cyclone Activity (NTC) (103%)	75	90	15	90	105

POST-31 JULY PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL ON EACH OF THE FOLLOWING UNITED STATES COASTAL AREAS:

1) Entire U.S. coastline - 48% (full-season average for last century is 52%)
2) U.S. East Coast Including Peninsula Florida - 28% (full-season average for last century is 31%)
3) Gulf Coast from the Florida Panhandle westward to Brownsville - 28% (full-season average for last century is 30%)

POST-31 JULY PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE TRACKING INTO THE CARIBBEAN (10-20°N, 60-88°W)

1) 39% (full-season average for last century is 42%)

POST-31 JULY HURRICANE IMPACT PROBABILITIES FOR 2012 (NUMBERS IN PARENTHESES ARE LONG-PERIOD FULL SEASON AVERAGES)

State	Hurricane	Major Hurricane
Texas	30% (33%)	11% (12%)
Louisiana	28% (30%)	11% (12%)
Mississippi	10% (11%)	4% (4%)
Alabama	14% (16%)	2% (3%)
Florida	47% (51%)	19% (21%)
Georgia	10% (11%)	1% (1%)
South Carolina	16% (17%)	3% (4%)
North Carolina	26% (28%)	7% (8%)
Virginia	6% (6%)	1% (1%)
Maryland	1% (1%)	<1% (<1%)
Delaware	1% (1%)	<1% (<1%)
New Jersey	1% (1%)	<1% (<1%)
New York	7% (8%)	3% (3%)
Connecticut	6% (7%)	2% (2%)
Rhode Island	5% (6%)	2% (3%)
Massachusetts	6% (7%)	2% (2%)
New Hampshire	1% (1%)	<1% (<1%)
Maine	3% (4%)	<1% (<1%)

POST-31 JULY PROBABILITIES OF HURRICANES AND MAJOR HURRICANES TRACKING WITHIN 100 MILES OF EACH ISLAND OR LANDMASS FOR 2012 (NUMBERS IN PARENTHESES ARE LONG-PERIOD FULL SEASON AVERAGES)

Island/Landmass	Hurricane within 100 Miles	Major Hurricane within 100 Miles
Bahamian Islands	48% (51%)	27% (30%)
Cuba	48% (52%)	25% (28%)
Haiti	25% (27%)	12% (13%)
Jamaica	23% (25%)	10% (11%)
Mexico (East Coast)	54% (57%)	21% (23%)
Puerto Rico	26% (29%)	12% (13%)
Turks and Caicos	22% (24%)	9% (9%)
US Virgin Islands	27% (30%)	11% (12%)

Please also visit the Landfalling Probability Webpage at http://www.e-transit.org/hurricane for landfall probabilities for 11 U.S. coastal regions and 205 coastal and near-coastal counties from Brownsville, Texas to Eastport, Maine as well as probabilities for every island in the Caribbean. We suggest that all coastal residents visit the Landfall Probability Webpage for their individual location probabilities.

ABSTRACT

Information obtained through July 2012 indicates that the remainder of the 2012 Atlantic hurricane season will be slightly less active than the average 1981-2010 season. We estimate that the remainder of 2012 will have about 5 hurricanes (average is 5.5), 10 named storms (average is 10.5), 37.25 named storm days (average is 58), 19.25 hurricane days (average is 21.3), 2 major (Category 3-4-5) hurricanes (average is 2.0) and 5 major hurricane days (average is 3.9). The probability of U.S. major hurricane landfall and Caribbean major hurricane activity for the remainder of the 2012 season is estimated to be slightly below its long-period average. We expect the remainder of the Atlantic basin hurricane season to accrue Net Tropical Cyclone (NTC) activity of approximately 90 percent of the seasonal average. We have increased our seasonal forecast from early April and early June, due to a combination of uncertainty in El Niño as well as slightly more favorable tropical Atlantic conditions.

This forecast was based on a newly-developed extended-range early August statistical prediction scheme developed over the previous 33 years. Our two older statistical forecast models that have been utilized for the past few years were consulted. Analog predictors were also considered.

The ENSO-related warming trend in the tropical Pacific has slackened somewhat in recent weeks, and we are unsure as to how much of an impact El Niño will have on this year's hurricane season. The combination of the uncertainty in tropical Pacific conditions along with the low sea level pressure anomalies observed in recent weeks over the tropical Atlantic have led us to increase our forecast slightly.

Starting today and issued every two weeks following (e.g., August 17, August 31, etc), we will issue two-week forecasts for Atlantic TC activity during the peak of the Atlantic hurricane season from August-October. A late-season forecast for the Caribbean basin will be issued on Monday, October 1.

Why issue forecasts for seasonal hurricane activity?

We are frequently asked this question. Our answer is that it is possible to say something about the probability of the coming year's hurricane activity which is superior to climatology. The Atlantic basin has the largest year-to-year variability of any of the global tropical cyclone basins. People are curious to know how active the upcoming season is likely to be, particularly if you can show hindcast skill improvement over climatology for many past years.

Everyone should realize that it is impossible to precisely predict this season's hurricane activity in early August. There is, however, much curiosity as to how global ocean and atmosphere features are presently arranged as regards to the probability of an active or inactive hurricane season for the coming year. Our new early August statistical forecast methodology shows strong evidence over 33 past years that improvement over climatology can be attained. We utilize this newly-developed model along with two older August statistical models when issuing this year's forecast. **We would never issue a seasonal hurricane forecast unless we had a statistical model constructed over a long hindcast period which showed significant skill over climatology.**

We issue these forecasts to satisfy the curiosity of the general public and to bring attention to the hurricane problem. There is a general interest in knowing what the odds are for an active or inactive season. One must remember that our forecasts are based on the premise that those global oceanic and atmospheric conditions which preceded comparatively active or inactive hurricane seasons in the past provide meaningful information about similar trends in future seasons. This is not always true for individual seasons. It is also important that the reader appreciate that these seasonal forecasts are based on statistical schemes which, owing to their intrinsically probabilistic nature, will fail in some years. Moreover, these forecasts do not specifically predict where within the Atlantic basin these storms will strike. The probability of landfall for any one location along the coast is very low and reflects the fact that, in any one season, most U.S. coastal areas will not feel the effects of a hurricane no matter how active the individual season is.

DEFINITIONS AND ACRONYMS

Accumulated Cyclone Energy (ACE) - A measure of a named storm's potential for wind and storm surge destruction defined as the sum of the square of a named storm's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence. The 1950-2000 average value of this parameter is 96 for the Atlantic basin.

Atlantic Multi-Decadal Oscillation (AMO) – A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the oceanic thermohaline circulation. Although several definitions of the AMO are currently used in the literature, we define the AMO based on North Atlantic sea surface temperatures from 50-60°N, 10-50°W.

Atlantic Basin – The area including the entire North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico.

El Niño – A 12-18 month period during which anomalously warm sea surface temperatures occur in the eastern half of the equatorial Pacific. Moderate or strong El Niño events occur irregularly, about once every 3-7 years on average.

Hurricane (H) - A tropical cyclone with sustained low-level winds of 74 miles per hour (33 ms^{-1} or 64 knots) or greater.

Hurricane Day (HD) - A measure of hurricane activity, one unit of which occurs as four 6-hour periods during which a tropical cyclone is observed or is estimated to have hurricane-force winds.

Madden Julian Oscillation (MJO) – A globally propagating mode of tropical atmospheric intra-seasonal variability. The wave tends to propagate eastward at approximately 5 ms^{-1}, circling the globe in roughly 40-50 days.

Main Development Region (MDR) – An area in the tropical Atlantic where a majority of major hurricanes form, which we define as 10-20°N, 20-70°W.

Major Hurricane (MH) - A hurricane which reaches a sustained low-level wind of at least 111 mph (96 knots or 50 ms^{-1}) at some point in its lifetime. This constitutes a category 3 or higher on the Saffir/Simpson scale.

Major Hurricane Day (MHD) - Four 6-hour periods during which a hurricane has an intensity of Saffir/Simpson category 3 or higher.

Multivariate ENSO Index (MEI) – An index defining ENSO that takes into account tropical Pacific sea surface temperatures, sea level pressures, zonal and meridional winds and cloudiness.

Named Storm (NS) - A hurricane, a tropical storm or a sub-tropical storm.

Named Storm Day (NSD) - As in HD but for four 6-hour periods during which a tropical or sub-tropical cyclone is observed (or is estimated) to have attained tropical storm-force winds.

Net Tropical Cyclone (NTC) Activity –Average seasonal percentage mean of NS, NSD, H, HD, MH, MHD. Gives overall indication of Atlantic basin seasonal hurricane activity. The 1950-2000 average value of this parameter is 100.

Saffir/Simpson Hurricane Wind Scale – A measurement scale ranging from 1 to 5 of hurricane wind intensity. One is a weak hurricane; whereas, five is the most intense hurricane.

Southern Oscillation Index (SOI) – A normalized measure of the surface pressure difference between Tahiti and Darwin. Low values typically indicate El Niño conditions.

Sea Surface Temperature – SST

Sea Surface Temperature Anomaly – SSTA

Thermohaline Circulation (THC) – A large-scale circulation in the Atlantic Ocean that is driven by fluctuations in salinity and temperature. When the THC is stronger than normal, the AMO tends to be in its warm (or positive) phase, and more Atlantic hurricanes typically form.

Tropical Cyclone (TC) - A large-scale circular flow occurring within the tropics and subtropics which has its strongest winds at low levels; including hurricanes, tropical storms and other weaker rotating vortices.

Tropical North Atlantic (TNA) index – A measure of sea surface temperatures in the area from 5.5-23.5°N, 15-57.5°W.

Tropical Storm (TS) - A tropical cyclone with maximum sustained winds between 39 mph (18 ms^{-1} or 34 knots) and 73 mph (32 ms^{-1} or 63 knots).

Vertical Wind Shear – The difference in horizontal wind between 200 mb (approximately 40000 feet or 12 km) and 850 mb (approximately 5000 feet or 1.6 km).

1 knot = 1.15 miles per hour = 0.515 meters per second

1 Introduction

This is the 29th year in which the CSU Tropical Meteorology Project has made forecasts of the upcoming season's Atlantic basin hurricane activity. Our research team has shown that a sizable portion of the year-to-year variability of Atlantic tropical cyclone (TC) activity can be hindcast with skill exceeding climatology. This year's August forecast is based on a new statistical methodology derived from 33 years of past data along with two earlier August forecast schemes. Qualitative adjustments are added to accommodate additional processes which may not be explicitly represented by our statistical analyses. These evolving forecast techniques are based on a variety of climate-related global and regional predictors previously shown to be related to the forthcoming seasonal Atlantic basin TC activity and landfall probability. We believe that seasonal forecasts must be based on methods that show significant hindcast skill in application to long periods of prior data. It is only through hindcast skill that one can demonstrate that seasonal forecast skill is possible. This is a valid methodology provided that the atmosphere continues to behave in the future as it has in the past.

The best predictors do not necessarily have the best individual correlations with hurricane activity. The best forecast parameters are those that explain the portion of the variance of seasonal hurricane activity that is not associated with the other forecast variables. It is possible for an important hurricane forecast parameter to show little direct relationship to a predictand by itself but to have an important influence when included with a set of 2-3 other predictors.

A direct correlation of a forecast parameter may not be the best measure of the importance of this predictor to the skill of a 3-4 parameter forecast model. This is the nature of the seasonal or climate forecast problem where one is dealing with a very complicated atmospheric-oceanic system that is highly non-linear. There is a maze of changing physical linkages between the many variables. These linkages can undergo unknown changes from weekly to decadal time scales. It is impossible to understand how all these processes interact with each other. No one can completely understand the full complexity of the atmosphere-ocean system. But, it is still possible to develop a reliable statistical forecast scheme which incorporates a number of the climate system's non-linear interactions. Any seasonal or climate forecast scheme should show significant hindcast skill before it is used in real-time forecasts.

1.1 2012 Atlantic Basin Activity through July

The 2012 Atlantic basin hurricane season has had above-average TC activity, based on the ACE index, during May through July.

Alberto formed late on May 19 from an area of low pressure off of the South Carolina coast. A blocking pattern over the mid-Atlantic forced Alberto southwestward early in its lifetime. A mid-level trough caused the system to recurve out to sea before it could make landfall along the northeast Florida coastline. Relatively strong vertical shear and dry air prevented Alberto from strengthening beyond a 45-knot tropical storm. It was declared a remnant low on May 22.

Beryl formed off of the South Carolina coast as a sub-tropical cyclone on May 26. A ridge built near Beryl which drove the system southwestward towards the Florida coast. By the following day, Beryl began to intensify as it moved over warmer water, and it completed its transition to a tropical cyclone. The system made landfall as a 60-knot tropical cyclone near Jacksonville Beach, FL on May 28. It maintained tropical depression status as it began to recurve into the mid-latitudes, eventually being declared extra-tropical on May 30. Beryl was the strongest tropical cyclone on record to make US landfall outside of the hurricane season.

Chris developed from a low pressure area while moving northeast away from Bermuda. Low wind shear and relatively warm SSTs allowed for Chris to become a tropical cyclone on June 19. Despite moving over progressively cooler water, Chris surprisingly intensified briefly into a hurricane before weakening to a tropical storm again on June 21. It transitioned into an extra-tropical cyclone the following day.

Debby developed in the northern Gulf of Mexico from a low pressure area on June 23. It intensified briefly before encountering relatively strong vertical shear and dry air which caused it to weaken to a marginal tropical storm before making landfall near Steinhatchee, Florida on June 26. It dissipated soon thereafter. Debby caused significant flooding in north Florida while transiting the state. It soon recurved and was declared post-tropical on June 27.

Table 1 records observed Atlantic basin TC activity through 31 July, while tracks through 31 July are displayed in Figure 1. All TC activity calculations are based upon data available in the National Hurricane Center's b-decks.

Table 1: Observed 2012 Atlantic basin tropical cyclone activity through July.

Highest Category	Name	Dates	Peak Sustained Winds (kts)/lowest SLP (mb)	NSD	HD	MHD	ACE	NTC
TS	Alberto	May 19 - May 21	50 kt/995 mb	2.50			1.7	2.6
TS	Beryl	May 26 - May 28	60 kt/993 mb	3.50			3.4	2.9
H-1	Chris	June 19 - June 22	65 kt/987 mb	4.75	0.75		5.6	6.7
TS	Debby	June 23 - June 26	50 kt/990 mb	4.00			3.2	3.1
Totals	4			14.75	0.75		13.8	15.3

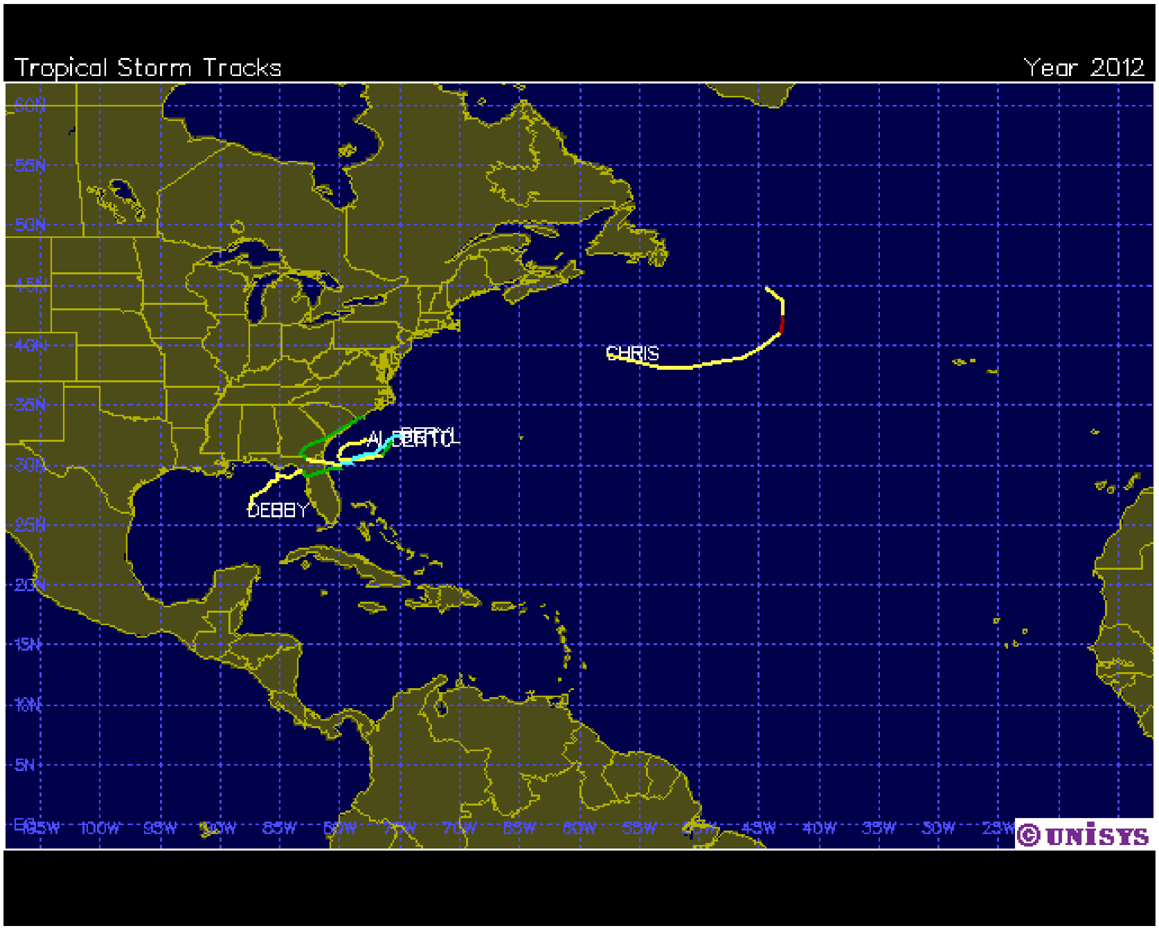


Figure 1: 2012 Atlantic basin hurricane tracks through July. Figure courtesy of Unisys Weather (http://weather.unisys.com).

2 Newly-Developed 1 August Forecast Scheme

We have devised a new 1 August statistical seasonal forecast scheme for the prediction of Net Tropical Cyclone (NTC) activity this year. This model uses a total of three predictors, all of which are selected from the ERA-Interim Reanalysis dataset, which is available from 1979-2011. The major components of the forecast scheme are discussed in the next few paragraphs.

The pool of three predictors for this new early August statistical forecast scheme is given and defined in Table 2. The location of each of these predictors is shown in Figure 2. Skillful forecasts can be issued for post-31 July NTC based upon hindcast results over the period from 1979-2011. When these three predictors are combined, they correlate at 0.91 with observed NTC using a drop-one cross validation approach over the period from 1979-2011 (Figure 3).

Table 2: Listing of 1 August 2012 predictors for this year's hurricane activity using the new statistical model. A plus (+) means that positive deviations of the parameter indicate increased hurricane activity this year, and a minus (-) means that positive deviations of the parameter indicate decreased hurricane activity this year. The combination of these three predictors calls for a slightly below-average hurricane season.

Predictor	Values for 2012 Forecast	Effect on 2012 Hurricane Season
1) July Surface U (10-17.5°N, 60-85°W) (+)	-0.6 SD	Suppress
2) July Surface Temperature (20-40°N, 15-35°W) (+)	+0.5 SD	Enhance
3) July 200 mb U (5-15°N, 0-40°E) (-)	+0.7 SD	Suppress

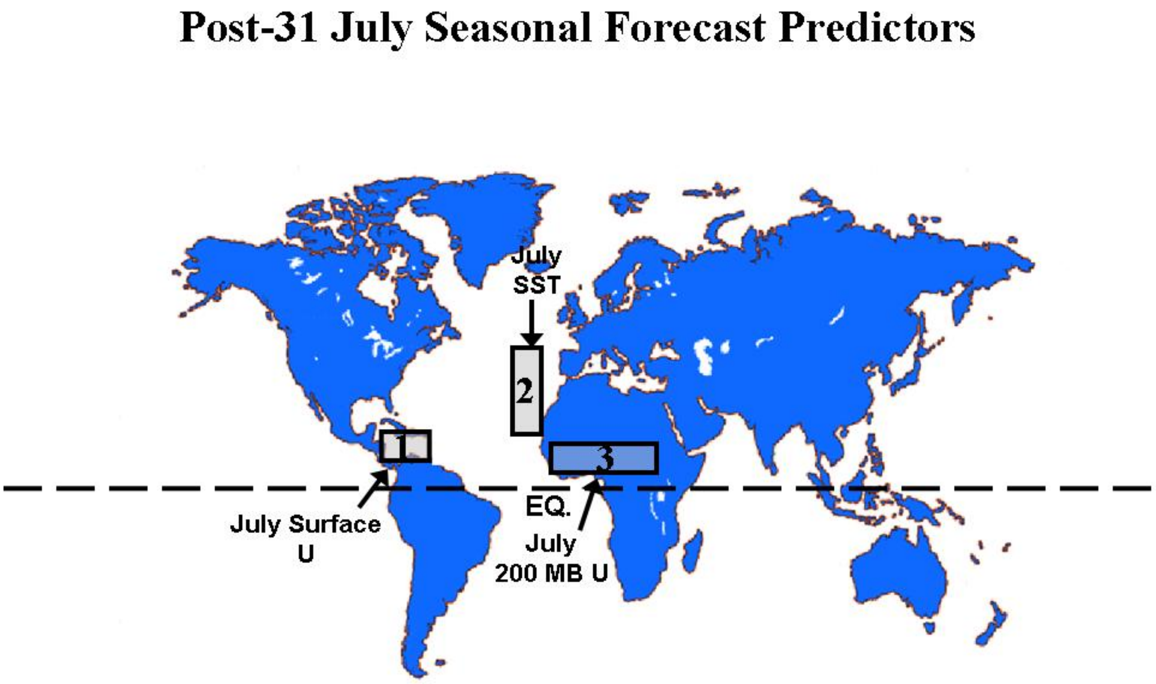


Figure 2: Location of predictors for the post-31 July forecast for the 2012 hurricane season from the new statistical model.

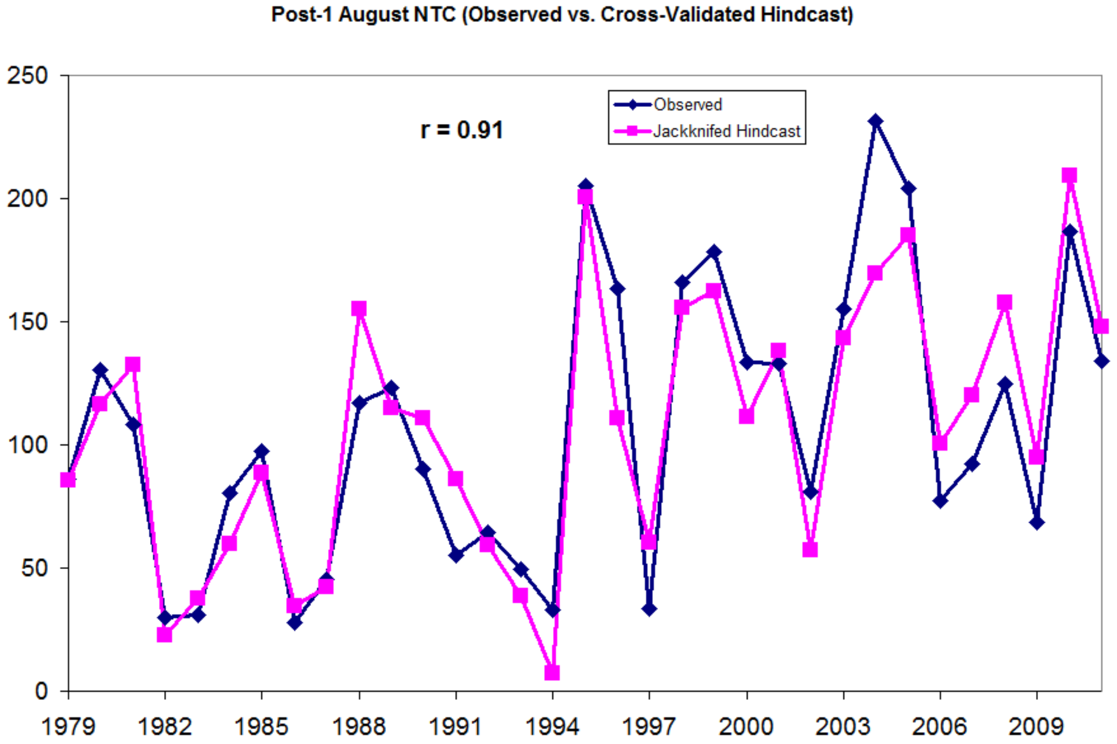


Figure 3: Observed versus hindcast values of post-31 July NTC for 1979-2011 using the new statistical scheme - a very skillful hindcast verification.

Table 3 shows our statistical forecast for the 2012 hurricane season from the new statistical model and the comparison of this forecast with the 1981-2010 median. Our statistical forecast is calling for slightly below-average activity this year.

Table 3: Post-31 July statistical forecast for 2012 from the new statistical model.

Predictands and Climatology (1981-2010 Post-31 July Median)	Statistical Forecast
Named Storms (NS) – 10.5	9.5
Named Storm Days (NSD) – 58.0	43.6
Hurricanes (H) – 5.5	5.1
Hurricane Days (HD) – 21.3	18.2
Major Hurricanes (MH) – 2.0	1.9
Major Hurricane Days (MHD) – 3.8	3.9
Accumulated Cyclone Energy Index (ACE) – 86	75
Net Tropical Cyclone Activity (NTC) – 95	84

Table 4 displays our early August cross-validated hindcasts for 1979-2011 using the new statistical scheme, while Figure 3 displays observations versus NTC cross-validated hindcasts. Our early August model has correctly predicted above- or below-average post-31 July NTC in 29 out of 33 years (88%). These hindcasts have had a smaller error than climatology in 24 out of 33 years (73%). Our average hindcast errors have been 19 NTC units, compared with 47 NTC units had we used only climatology.

Table 4: Observed versus hindcast post-31 July NTC for 1979-2011 using the new statistical scheme. Average errors for hindcast NTC and climatological NTC predictions are given without respect to sign. Red bold-faced years in the “Hindcast NTC” column are years that we did not go the right way, while red bold-faced years in the “Hindcast improvement over Climatology” column are years that we did not beat climatology. **The hindcast went the right way with regards to an above- or below-average season in 29 out of 33 years (88%), while hindcast improvement over climatology occurred in 24 out of 33 years (73%).**

Year	Observed NTC	Hindcast NTC	Observed minus Hindcast	Observed minus Climatology	Hindcast improvement over Climatology
1979	86	85	1	-9	8
1980	130	117	14	35	22
1981	108	132	-24	13	**-11**
1982	30	22	7	-65	58
1983	31	38	-7	-64	57
1984	80	60	21	-15	**-6**
1985	97	**88**	9	2	**-7**
1986	28	35	-7	-67	60
1987	46	43	3	-49	46
1988	117	155	-38	22	**-16**
1989	123	115	8	28	20
1990	90	**111**	-21	-5	**-16**
1991	55	86	-31	-40	9
1992	65	59	5	-30	25
1993	50	39	11	-45	35
1994	33	7	26	-62	36
1995	205	201	4	110	106
1996	163	111	53	68	16
1997	33	61	-27	-62	34
1998	166	156	10	71	61
1999	178	162	16	83	67
2000	134	112	22	39	17
2001	133	138	-5	38	33
2002	81	57	24	-14	**-10**
2003	155	143	12	60	48
2004	232	170	62	137	75
2005	204	185	19	109	90
2006	77	**101**	-23	-18	**-6**
2007	92	**120**	-28	-3	**-25**
2008	125	158	-33	30	**-3**
2009	69	95	-26	-26	0
2010	187	209	-22	92	69
2011	134	148	-14	39	25
Average	**107**	**107**	**|19|**	**|47|**	**+28***

* This shows that we obtain a net (28/47) or 60 percent improvement over the year-to-year variance from climatology.

2.2 Physical Associations among Predictors Listed in Table 2

The locations and brief descriptions of the three predictors for our new August statistical forecast are now discussed. It should be noted that all forecast parameters correlate significantly with physical features during August through October that are known to be favorable for elevated levels of TC activity. For each of these predictors, we display a four-panel figure showing linear correlations between values of each predictor and August-October values of SST, sea level pressure (SLP), 850 mb (~1.5 km altitude) zonal wind (U), and 200 mb (~12 km altitude) zonal wind (U), respectively.

Predictor 1. July Surface U in the Caribbean (+)

(10-17.5°N, 60-85°W)

Low-level trade wind flow has been utilized as a predictor in seasonal forecasting systems for the Atlantic basin (Lea and Saunders 2004). When the trades are weaker-than-normal, SSTs across the tropical Atlantic tend to be elevated, and consequently a larger-than-normal Atlantic Warm Pool (AWP) is typically observed (Wang and Lee 2007) (Figure 4). A larger AWP also correlates with reduced vertical shear across the tropical Atlantic. Weaker trade winds are typically associated with higher pressure in the tropical eastern Pacific (a La Niña signal) and lower pressure in the Caribbean and tropical Atlantic. Both of these conditions are typically associated with an active hurricane season. Predictor 1 also has a strong negative correlation with August-October-averaged 200-850-mb zonal shear.

Predictor 2. July Surface Temperature in the Northeastern Subtropical Atlantic (+)

(20°-40°N, 15-35°W)

A similar predictor was utilized in earlier August seasonal forecast models (Klotzbach 2007, Klotzbach 2011). Anomalously warm SSTs in the subtropical North Atlantic are associated with a positive phase of the Atlantic Meridional Mode (AMM), a northward-shifted Intertropical Convergence Zone, and consequently, reduced trade wind strength (Kossin and Vimont 2007). Weaker trade winds are associated with less surface evaporative cooling and less mixing and upwelling. This results in warmer tropical Atlantic SSTs during the August-October period (Figure 5).

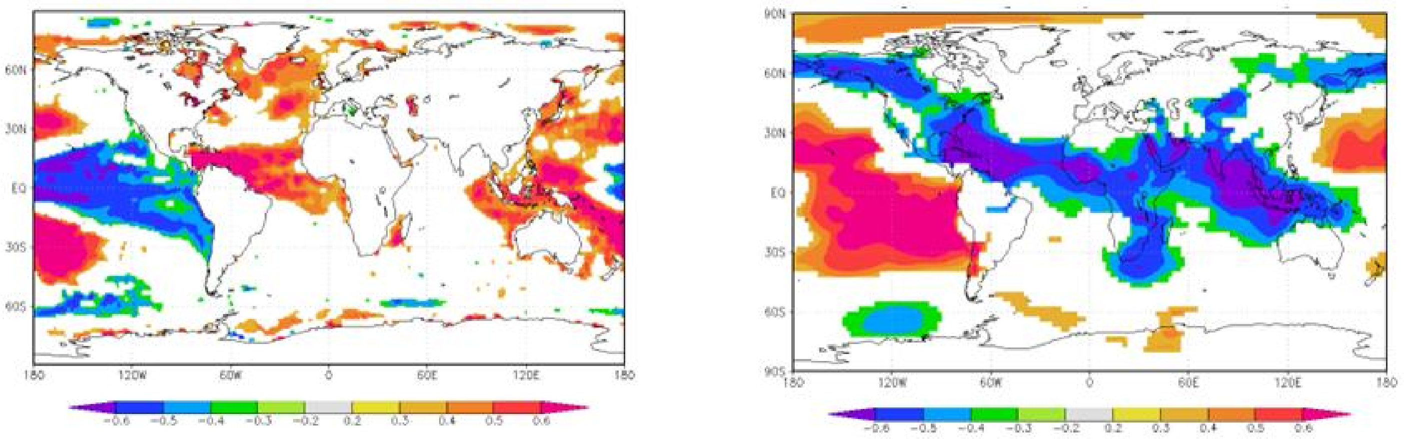
Predictor 3. July 200 mb U over Northern Tropical Africa (-)

(5-15°N, 0-40°E)

Anomalous easterly flow at upper levels over northern tropical Africa provides an environment that is more favorable for easterly wave development into TCs. This anomalous easterly flow tends to persist through August-October, which reduces shear over the Main Development Region (MDR). This predictor also correlates with SLP and SST anomalies over the tropical eastern Pacific that are typically associated with ENSO conditions (Figure 6).

August-October Correlations w/ Predictor 1 (1979-2011) (July Surface U)

(a) SST (b) SLP



(c) 850 mb U (d) 200 mb U

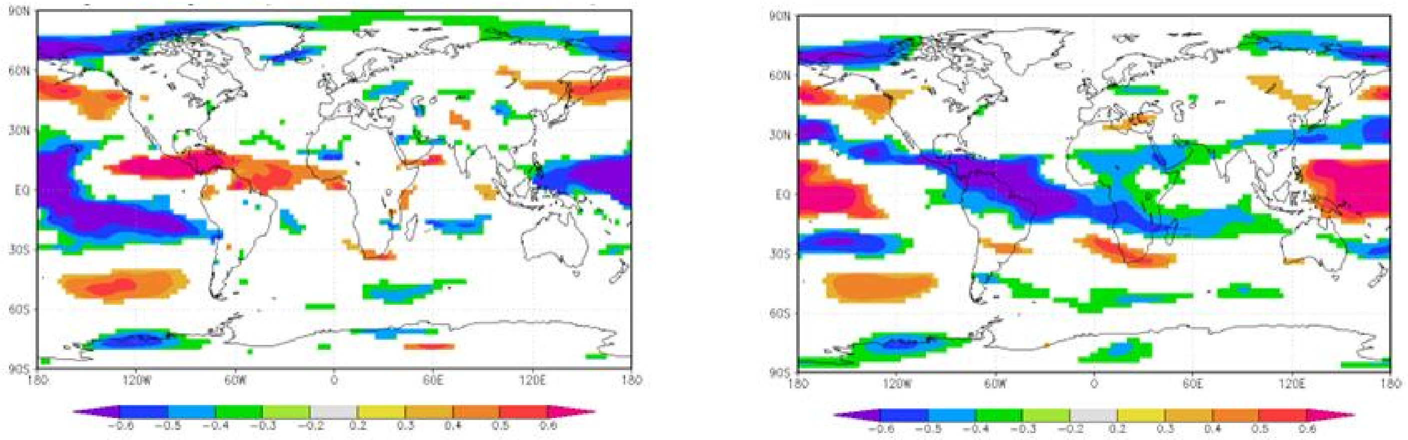


Figure 4: Linear correlations between July Surface U in the Caribbean (Predictor 1) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d).

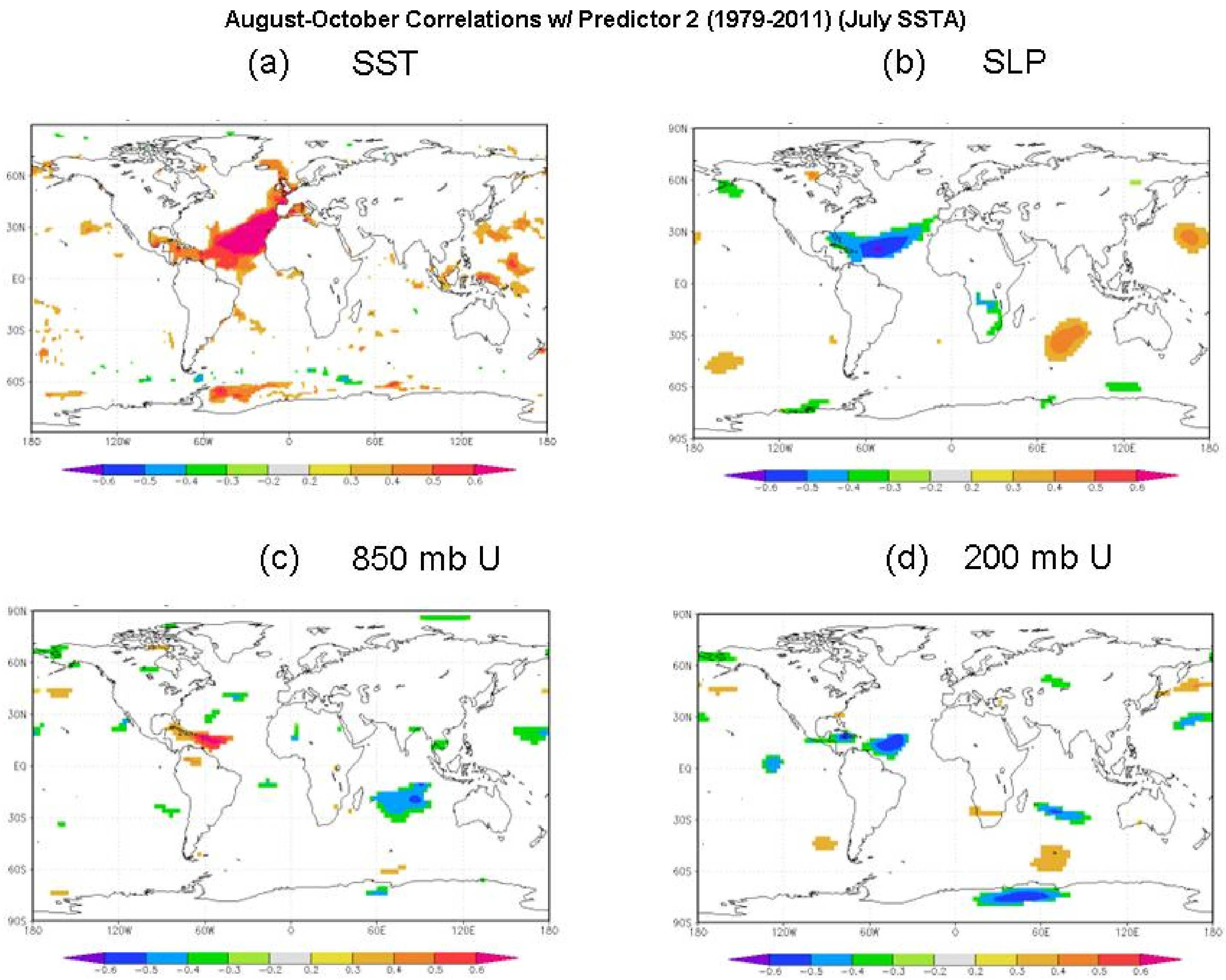


Figure 5: Linear correlations between July Surface Temperature in the Subtropical Northeastern Atlantic (Predictor 2) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 850 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d).

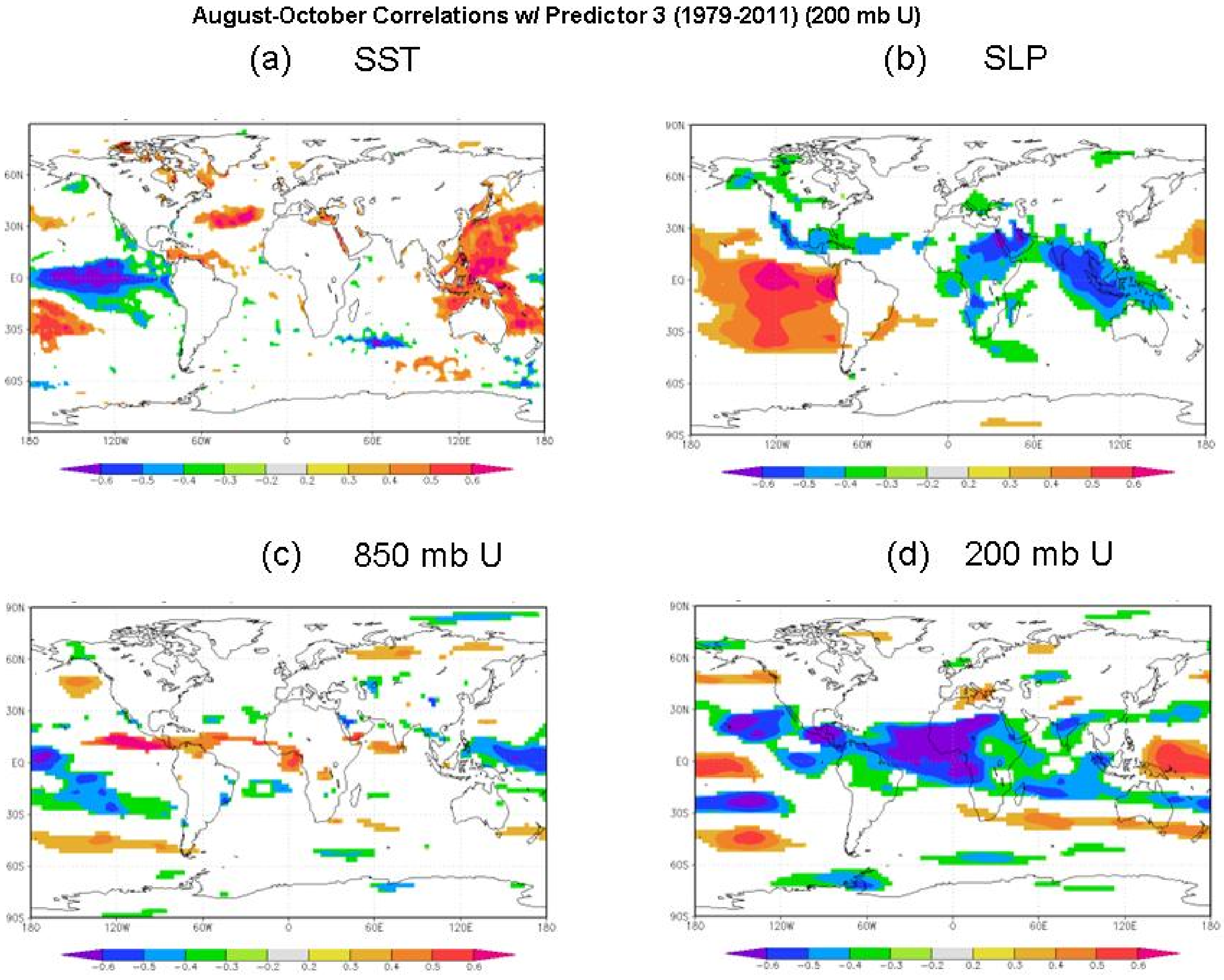


Figure 6: Linear correlations between <u>July 200 MB Zonal Wind</u> over tropical north Africa <u>(Predictor 3)</u> and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d). The color scale has been reversed so that the correlations match up with those in Figures 4 and 5.

Table 5 summarizes the statistical model output from the new forecast as well as earlier statistical models discussed in detail in Klotzbach (2011) and Klotzbach (2007), respectively. The newly-developed model calls for slightly below-average activity, the Klotzbach (2011) model calls for average activity, while the Klotzbach (2007) model calls for slightly above-average activity.

Table 5: Summary of output from the Klotzbach (2007) and Klotzbach (2011) statistical models for post-31 July tropical cyclone activity as well as the new forecast model (Klotzbach 2012).

Predictands and Climatology (1950-2000 – Post-31 July Average)	Klotzbach (2007)	Klotzbach (2011)	Klotzbach (2012)
Named Storms (NS) - 10.5	11.4	10.7	9.5
Named Storm Days (NSD) – 58.0	57.7	53.0	43.6
Hurricanes (H) – 5.5	6.6	6.1	5.1
Hurricane Days (HD) – 21.3	26.6	23.8	18.2
Major Hurricanes (MH) – 2.0	2.9	2.6	1.9
Major Hurricane Days (MHD) – 3.8	7.0	6.0	3.9
Accumulated Cyclone Energy Index (ACE) – 86	110	99	75
Net Tropical Cyclone Activity (NTC) – 95	120	108	84

3 Forecast Uncertainty

One of the questions that we are asked regarding our seasonal hurricane predictions is the degree of uncertainty that is involved. Obviously, our predictions are our best estimate, but there is with all forecasts an uncertainty as to how well they will verify.

Table 6 provides our post-31 July forecast, with error bars (based on one standard deviation of absolute errors) as calculated from hindcasts/forecasts of the Klotzbach (2007) scheme over the 1990-2009 period, using equations developed over the 1950-1989 period. We typically expect to see 2/3 of our forecasts verify within one standard deviation of observed values, with 95% of forecasts verifying within two standard deviations of observed values.

Table 6: Model hindcast error and our 2012 hurricane forecast. Uncertainty ranges are given in one standard deviation (SD) increments.

Parameter	Hindcast Error (SD)	Post-31 July 2012 Forecast	Uncertainty Range – 1 SD (67% of Forecasts Likely in this Range)
Named Storms (NS)	2.3	9.5	7.2 - 11.8
Named Storm Days (NSD)	17.4	43.6	26.2 - 61.0
Hurricanes (H)	1.6	5.1	3.5 - 6.7
Hurricane Days (HD)	8.6	18.2	9.4 - 26.8
Major Hurricanes (MH)	0.9	1.9	1.0 – 2.8
Major Hurricane Days (MHD)	3.5	3.9	0.4 - 7.4
Accumulated Cyclone Energy (ACE)	36	75	39 - 111
Net Tropical Cyclone (NTC) Activity	34	84	50 - 118

4 Analog-Based Predictors for 2012 Hurricane Activity

Certain years in the historical record have global oceanic and atmospheric trends which are substantially similar to 2012. These years also provide useful clues as to likely trends in activity that the 2012 hurricane season may bring. For this early August forecast we determine which of the prior years in our database have distinct trends in key environmental conditions which are similar to current June-July 2012 conditions. Table 7 lists the best analog selections from our historical database.

We select prior hurricane seasons since 1950 which have similar atmospheric-oceanic conditions to those currently being experienced. We searched for years that had weak to moderate El Niño conditions and approximately average tropical Atlantic sea surface temperatures.

There were five hurricane seasons with characteristics most similar to what we observed in June-July 2012. The best analog years that we could find for the 2012 hurricane season were 1951, 1953, 1957, 2006 and 2009. We anticipate that 2012 seasonal hurricane activity will have activity that is in line with the average of these five analog years. <u>We believe that the remainder of 2012 will have slightly below-average activity in the Atlantic basin.</u>

Table 7: Best analog years for 2012 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1951	10	57.75	8	36.25	5	8.25	137	148
1953	14	64.50	6	18.00	4	6.75	104	127
1957	8	38.00	3	21.00	2	6.50	84	86
2006	10	52.75	5	21.25	2	2.00	79	85
2009	9	30.00	3	12.00	2	3.50	53	69
Mean (Full Season)	**10.2**	**48.6**	**5.0**	**21.7**	**3.0**	**5.4**	**91**	**102**
2012 Forecast (Full Season)	**14**	**52**	**6**	**20**	**2**	**5**	**99**	**105**
1981-2010 Median (Full Season)	**12.0**	**60.1**	**6.5**	**21.3**	**2.0**	**3.9**	**92**	**103**

5 ENSO

Neutral-to-warm ENSO conditions currently persist across the tropical Pacific. SST anomalies are now slightly above-average across the central and eastern tropical Pacific. Table 8 displays July and May SST anomalies for several Nino regions. Slight warming has occurred throughout most of the tropical Pacific over the past two months.

Table 8: May and July 2012 SST anomalies for Nino 1+2, Nino 3, Nino 3.4, and Nino 4, respectively. July-May SST anomaly differences are also provided.

Region	May SST Anomaly (°C)	July SST Anomaly (°C)	July minus May SST Change (°C)
Nino 1+2	1.2	0.9	-0.3
Nino 3	0.2	0.9	+0.7
Nino 3.4	-0.1	0.5	+0.6
Nino 4	-0.3	0.1	+0.4

It appears that a weak El Niño event is likely to be in place for the majority of the Atlantic hurricane season. The upper-ocean heat content in the central and eastern tropical Pacific is typically a good indicator of future trends in ENSO. Upper ocean heat content anomalies have generally continued their upward trend in recent weeks, indicating that a transition to El Niño is likely (Figure 7).

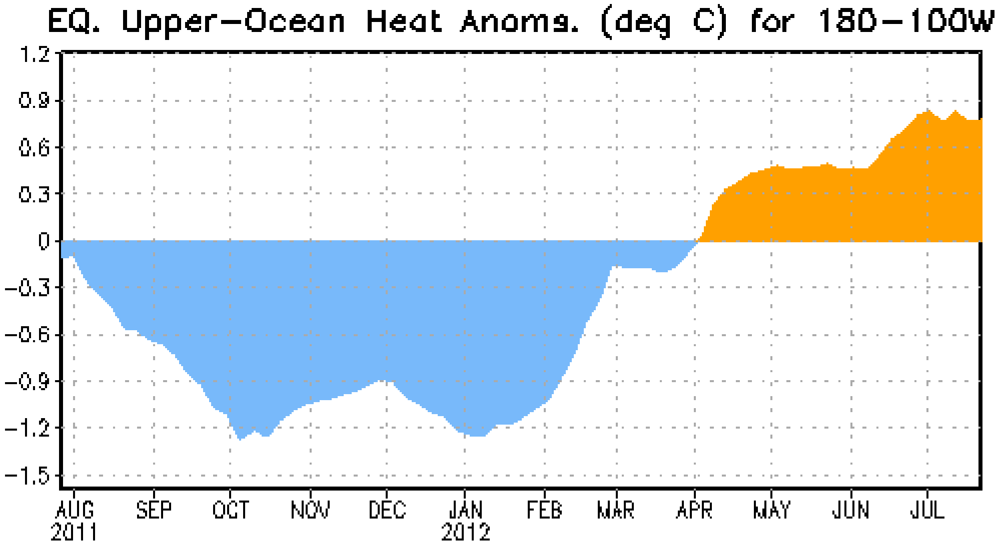


Figure 7: Central and eastern tropical Pacific upper ocean (0-300 meters) heat content anomalies over the past year. Note the significant warming of anomalies that has taken place since January 2012.

There is an increasing consensus amongst the various dynamical and statistical ENSO forecast models for a weak El Niño event to occur during the August-October period. The springtime ENSO predictability barrier is passing and the skill of forecast models tends to greatly improve. Figure 8 displays the current forecasts issued by various ENSO models. Most dynamical models are calling for a weak to moderate El Niño during the August-October period.

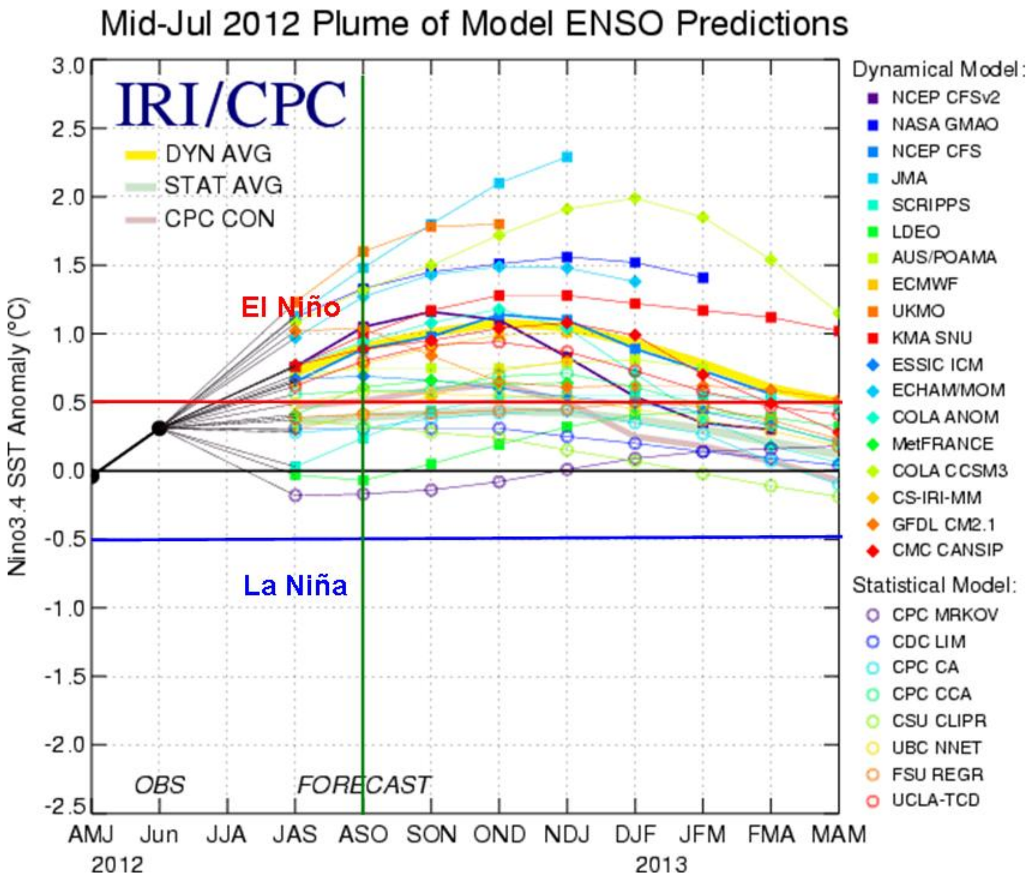


Figure 8: ENSO forecasts from various statistical and dynamical models. Figure courtesy of the International Research Institute (IRI).

As was found with the early June prediction, the European Centre for Medium-Range Weather Forecasts (ECMWF) typically shows the best prediction skill of the various ENSO models. The correlation skill between a 1 July forecast from the ECMWF model and the observed September Nino 3.4 anomaly is 0.89, based on hindcasts/forecasts from 1982-2010, explaining approximately 79% of the variance in Nino 3.4 SST. For reference, the correlation skill of a 1 May forecast from the ECMWF model was 0.82, indicating that approximately 15% additional variance can be explained by shortening the lead time of the forecast from 1 May to 1 July. The ECMWF model has recently been upgraded to system 4, indicating that improved ENSO skill may be possible. The average of the various ECMWF ensemble members is calling for a September Nino 3.4 SST anomaly of approximately 0.8°C, and approximately 3/4 of ensemble members call for SSTs to reach the El Niño threshold of 0.5°C in the Nino 3.4 region by September (Figure 9).

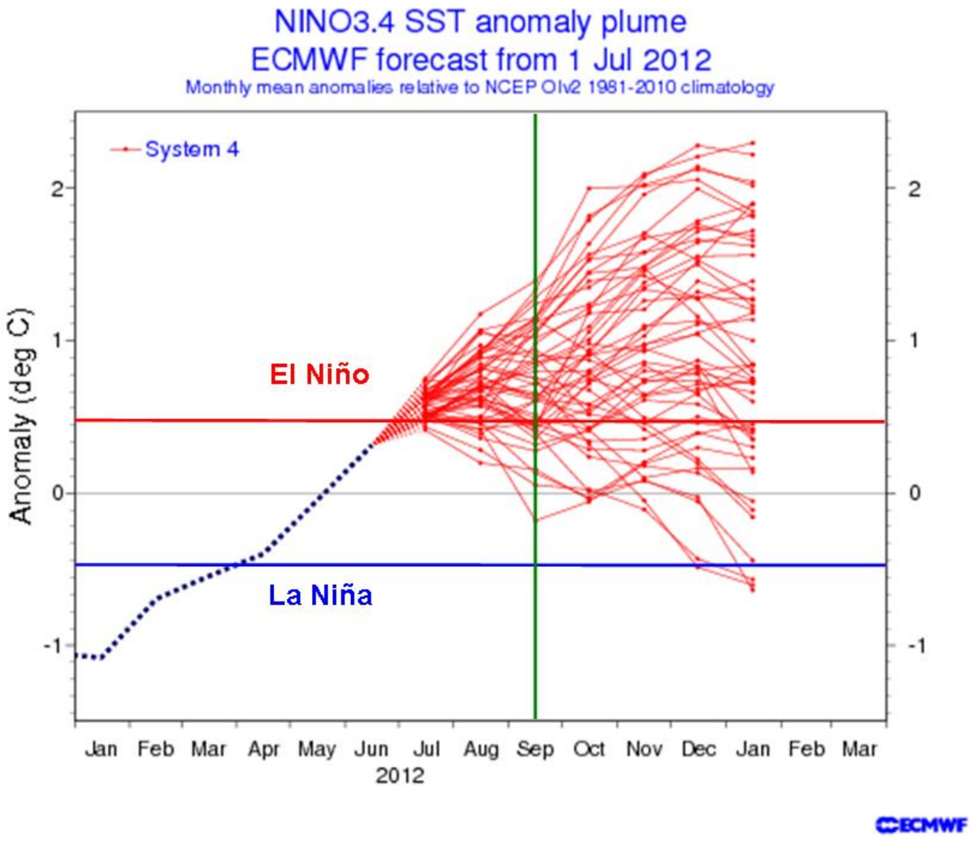


Figure 9: ECMWF ensemble model forecast for the Nino 3.4 region. Approximately 3/4 of ensemble members call for El Niño conditions by September.

Based on this information, our best estimate is that we will likely experience weak El Niño conditions during the 2012 hurricane season. A slightly stronger ENSO event could potentially significantly dampen the Atlantic basin hurricane season, while neutral ENSO conditions could potentially allow for much more TC activity than is being forecast here. Typically, El Niño reduces TC activity most significantly in October-November, especially in the Caribbean basin (Klotzbach 2011).

6 Current Atlantic Basin Conditions

Conditions in the Atlantic have become somewhat more favorable over the past two months. SST anomalies across the Main Development Region (MDR) have returned to near-average levels, while SSTs in the Caribbean are somewhat above average (Figure 10). Sea level pressure anomalies over the past month have been quite low, implying that the trade winds across the Main Development Region are weak and the Tropical Upper Tropospheric Trough (TUTT) is reduced in strength. A weakened TUTT typically relates to reduced vertical wind shear across the tropical Atlantic and Caribbean (Figure 11) (Knaff 1997).

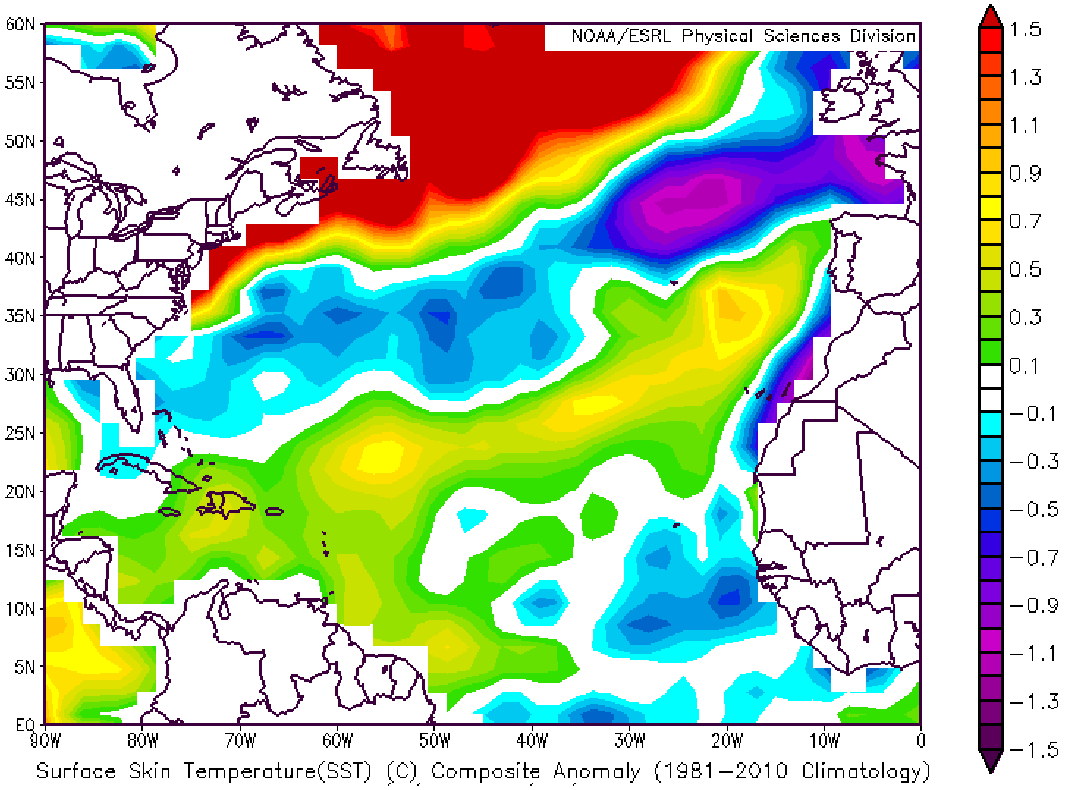


Figure 10: July 2012 SST anomaly. Note the positive anomalies throughout the tropical Atlantic and Caribbean.

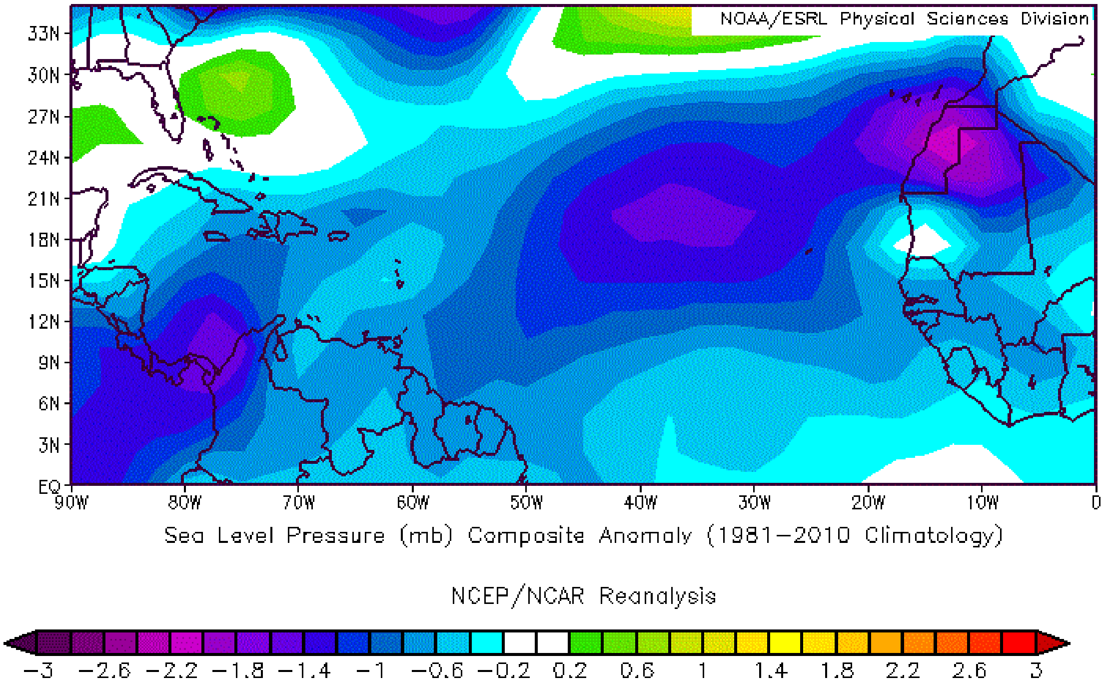


Figure 11: July 2012 Atlantic SLP anomaly. Note the negative anomalies throughout the tropical Atlantic and Caribbean.

Contradicting these more favorable conditions have been the copious amounts of dry air that have been prevalent over the tropical Atlantic during July. Figure 12 displays the 700-mb relative humidity anomalies for most of July throughout the tropical Atlantic and the Caribbean. Note that negative anomalies have been prevalent across most of the basin. Drier-than-normal mid-levels in the tropical Atlantic are typically associated with a more stable air mass which inhibits deep convection and the development of easterly waves into TCs.

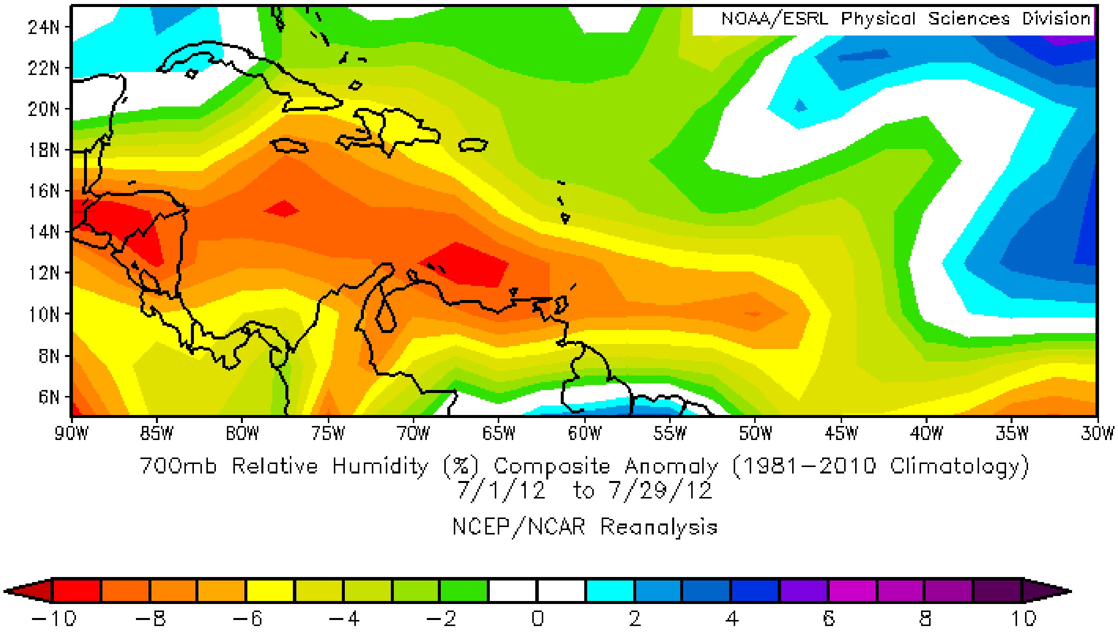


Figure 12: 700-mb RH anomalies across the tropical Atlantic from July 1 - July 29, 2012. Note that negative anomalies have been present across most of the basin during the period.

7 West Africa Conditions

Enhanced rainfall in the Sahel region of West Africa during the June-July time period has been associated with active hurricane seasons (Landsea and Gray 1992). Figure 13 displays a combined satellite/rain gauge estimate, referred to as the African Rainfall Estimation Algorithm Version 2 (RFE 2.0) of percent of normal rainfall over the June-July 2012 time period. In general, it appears that rainfall in the Western Sahel has been above normal during June and July. All other factors being equal, greater Western Sahel rainfall is favorable for enhanced hurricane activity.

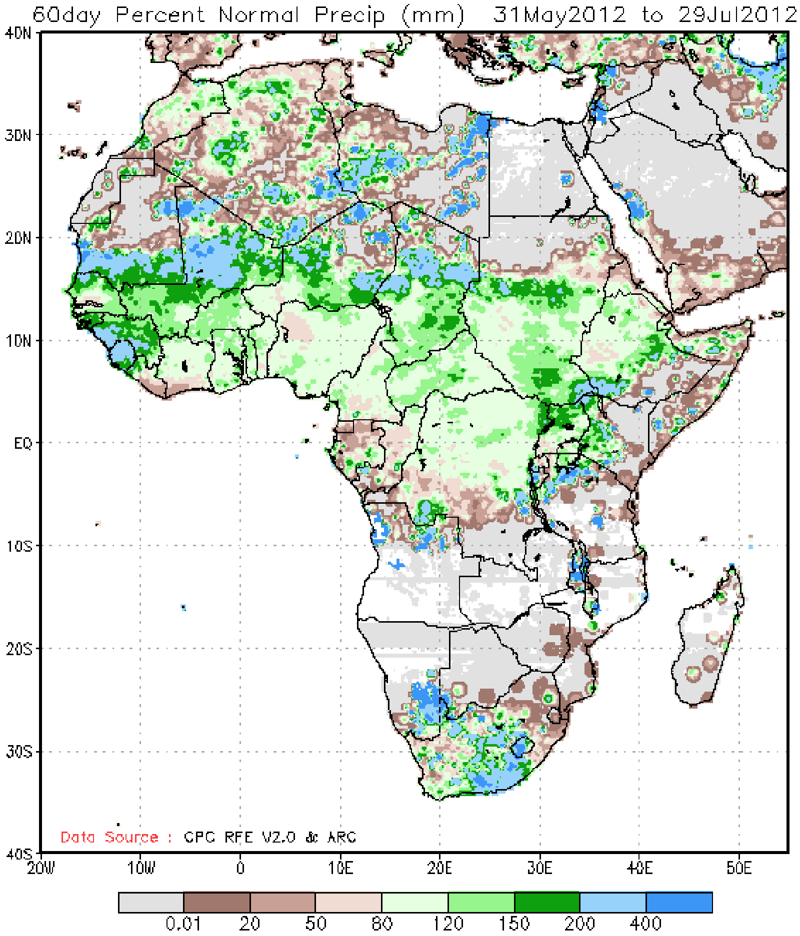


Figure 13: Rainfall Estimation Algorithm Version 2.0 (RFE) estimate of percent of normal rainfall for June-July 2012.

8 Adjusted 2012 Forecast

Table 9 shows our final adjusted early August forecast for the 2012 season which is a combination of our three statistical schemes (with May-July activity added in), our analog forecast and qualitative adjustments for other factors not explicitly contained in any of these schemes. The average of our three statistical forecasts (with May-July activity added in) and our analog forecast call for an average season (given that May-July was quite active). We foresee a slightly below-average remainder of the Atlantic hurricane season.

Table 9: May-July 2012 observed activity, our three early August full season statistical forecasts (with May-July 2012 activity added in), our analog forecast and our adjusted final forecast for the 2012 hurricane season.

Forecast Parameter and 1981-2010 Median (in parentheses)	May-July 2012 Observed Activity	Klotzbach (2007) Statistical Scheme	Klotzbach (2011) Statistical Scheme	New Statistical Scheme (2012)	Analog Scheme	Adjusted Final Forecast (Whole Season)
Named Storms (12.0)	4	15.4	14.7	13.5	10.2	14
Named Storm Days (60.1)	14.75	72.5	67.8	58.4	48.6	52
Hurricanes (6.5)	1	7.6	7.1	6.1	5.0	6
Hurricane Days (21.3)	0.75	27.4	24.6	20.1	21.7	20
Major Hurricanes (2.0)	0	2.9	2.6	1.9	3.0	2
Major Hurricane Days (3.9)	0	7.0	6.0	3.9	5.4	5
Accumulated Cyclone Energy Index (92)	14	124	113	91	91	99
Net Tropical Cyclone Activity (103%)	15	135	123	99	102	105

9 Landfall Probabilities for 2012

A significant focus of our recent research involves efforts to develop forecasts of the probability of hurricane landfall along the U.S. coastline and in the Caribbean. Whereas individual hurricane landfall events cannot be forecast months in advance, the total seasonal probability of landfall can be forecast with statistical skill. With the observation that landfall is a function of varying climate conditions, a probability specification has been developed through statistical analyses of all U.S. hurricane and named storm landfall events during the 20th century (1900-1999). Specific landfall probabilities can be given for all tropical cyclone intensity classes for a set of distinct U.S. coastal regions.

Net landfall probability is shown linked to the overall Atlantic basin Net Tropical Cyclone activity (NTC; see Table 10). NTC is a combined measure of the year-to-year mean of six indices of hurricane activity, each expressed as a percentage difference from the long-term average. Long-term statistics show that, on average, the more active the overall Atlantic basin hurricane season is, the greater the probability of U.S. hurricane landfall.

Table 10: NTC activity in any year consists of the seasonal total of the following six parameters expressed in terms of their long-term averages. A season with 10 NS, 50 NSD, 6 H, 25 HD, 3 MH, and 5 MHD would then be the sum of the following ratios: 10/9.6 = 104, 50/49.1 = 102, 6/5.9 = 102, 25/24.5 = 102, 3/2.3 = 130, 5/5.0 = 100, divided by six, yielding an NTC of 107.

	1950-2000 Average	
1)	Named Storms (NS)	9.6
2)	Named Storm Days (NSD)	49.1
3)	Hurricanes (H)	5.9
4)	Hurricane Days (HD)	24.5
5)	Major Hurricanes (MH)	2.3
6)	Major Hurricane Days (MHD)	5.0

Table 11 lists strike probabilities for the 2012 hurricane season for different TC categories for the entire U.S. coastline, the Gulf Coast and the East Coast including the Florida peninsula. We also issue probabilities for various islands and landmasses in the Caribbean and in Central America. Note that Atlantic basin post-1 August NTC activity in 2012 is expected to be slightly below its long-term average, and therefore, landfall probabilities are slightly below their long-term average.

As an example we find that the probability of Florida being hit by a major (Cat 3-4-5) hurricane during the remainder of this year is 19% which is slightly lower than the long-term climatological average of 21%.

South Florida is much more prone to being impacted by a hurricane on an individual-year basis compared with northeast Florida. For instance, the probability of Miami-Dade County being impacted by hurricane-force wind gusts for the remainder of this year is 10%. For Duval County in northeast Florida, the probability of being impacted by hurricane-force wind gusts is only 2%. However, considering a 50-year period, the probability of Duval County experiencing hurricane-force wind gusts is 75%.

For the island of Puerto Rico, the probability of a named storm, hurricane and major hurricane tracking within 50 miles of the island this year is 30%, 14%, and 4%, respectively.

Table 11: Estimated probability (expressed in percent) of one or more landfalling tropical storms (TS), category 1-2 hurricanes (HUR), category 3-4-5 hurricanes, total hurricanes and named storms along the entire U.S. coastline, along the Gulf Coast (Regions 1-4), and along the Florida Peninsula and the East Coast (Regions 5-11) for the remainder of the 2012 Atlantic hurricane season. Probabilities of a tropical storm, hurricane and major hurricane tracking into the Caribbean are also provided. The long-term mean annual probability of one or more landfalling systems during the last 100 years is given in parentheses.

Region	TS	Category 1-2 HUR	Category 3-4-5 HUR	All HUR	Named Storms
Entire U.S. (Regions 1-11)	76% (79%)	64% (68%)	48% (52%)	81% (84%)	95% (97%)
Gulf Coast (Regions 1-4)	55% (59%)	39% (42%)	28% (30%)	56% (60%)	80% (83%)
Florida plus East Coast (Regions 5-11)	47% (50%)	41% (44%)	28% (31%)	57% (61%)	77% (81%)
Caribbean (10-20°N, 60-88°W)	79% (82%)	53% (57%)	39% (42%)	71% (75%)	94% (96%)

10 Have Atmospheric CO_2 Increases Been Responsible for the Recent Large Upswing (since 1995) in Atlantic Basin Major Hurricanes?

A. BACKGROUND

The U.S. landfall of major hurricanes Dennis, Katrina, Rita and Wilma in 2005 and the four Southeast landfalling hurricanes of 2004 – Charley, Frances, Ivan and Jeanne, raised questions about the possible role that global warming played in those two unusually destructive seasons for the U.S. In addition, three hurricanes (Dolly, Gustav and Ike) pummeled the Gulf Coast in 2008 causing considerable devastation. Some researchers have tried to link the rising CO_2 levels with SST increases during the late 20th century and say that this has brought on higher levels of hurricane intensity.

These speculations that hurricane intensity has increased due to CO_2 increases have been given much media attention; however, we believe that they are not valid, given current observational data. The long manuscript by Gray (2011) goes into extensive detail describing why a significant relationship between increased CO_2 and increased Atlantic hurricane activity is not valid.

There has, however, been a large increase in Atlantic basin major hurricane activity in the last seventeen years (since 1995) in comparison with the prior 17-year period of 1978-1994 (Figure 14) as well as the prior quarter-century period of 1970-1994. It has been tempting for many who do not have a strong background of hurricane information to jump on this recent increase in major hurricane activity as strong evidence of a human influence on hurricanes. It should be noted, however, that the last 17-year active major hurricane period of 1995-2011 has not been more active than the earlier 17-year period of 1948-1964 when the Atlantic Ocean circulation conditions were similar to what has been observed during the last 17 years. These earlier active conditions occurred even though atmospheric CO_2 amounts and global SSTs were lower during this earlier period.

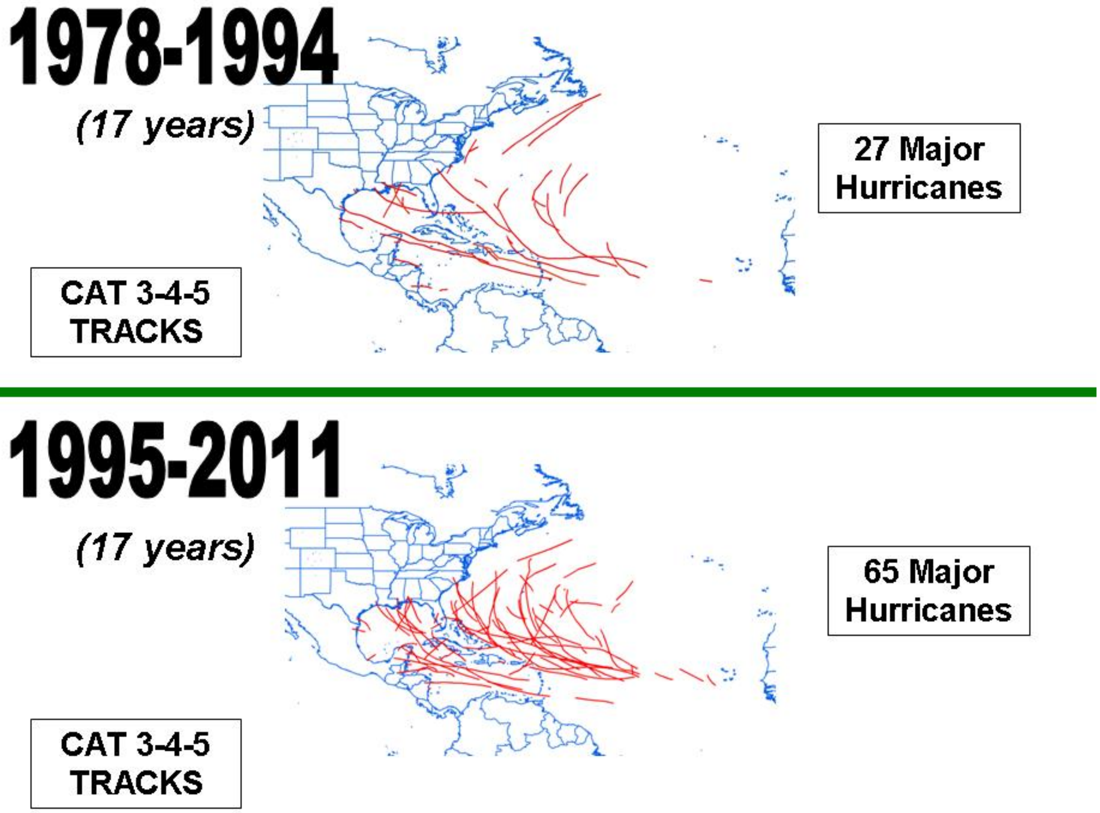


Figure 14: The tracks of major (Category 3-4-5) hurricanes during the 17-year period of 1995-2011 when the THC was strong versus the prior 17-year period of 1978-1994 when the THC was weak. Note that there were approximately 2.5 times as many major hurricanes when the THC was strong as when it was weak.

Table 12 shows how large Atlantic basin hurricane variations can be between strong and weak THC periods. Note especially how large the ratio is for major hurricane days (3.7) during strong vs. weak THC periods. Normalized U.S. hurricane damage studies by Pielke and Landsea (1998) and Pielke et al. (2008) show that landfalling major hurricanes account on average for about 80-85 percent of all hurricane-related destruction. This occurs even though these major hurricanes make up only 20-25 percent of named storms. This would give a general relative potential destructive difference of 3.7 * 4.25 or about 15 to 1.

Although global surface temperatures increased during the late 20th century, there is no reliable data to indicate increased hurricane frequency or intensity in any of the globe's other tropical cyclone basins since 1972. Global Accumulated Cyclone Energy (ACE), defined as the sum of the square of a named storm's maximum wind speed (in 10^4 knots^2) for each 6-hour period of its existence, shows significant year-to-year and decadal variability over the past forty years but no increasing trend (Figure 15). Similarly, Klotzbach (2006) found no significant change in global TC activity during the period from 1986-2005.

Table 12: Comparison of Atlantic annual basin hurricane activity in two 17-year periods when the Atlantic Ocean THC (or AMO) was strong versus an intermediate period (1970-1994) when the THC was weak.

	THC	SST (10-15°N; 70-40°W)	Avg. CO$_2$ ppm	NS	NSD	H	HD	MH	MHD	ACE	NTC
1948-1964 (17 years)	Strong	27.93	319	10.0	54.0	6.5	29.9	3.8	9.4	120	133
1970-1994 (25 years)	Weak	27.60	345	9.3	41.9	5.0	16.0	1.5	2.5	68	75
1995-2011 (17 years)	Strong	28.02	373	14.9	75.5	7.8	31.9	3.8	9.0	140	153
Annual Ratio Strong/Weak THC		Δ 0.35°C	~ 0	1.3	1.5	1.4	1.9	2.5	3.7	1.9	1.9

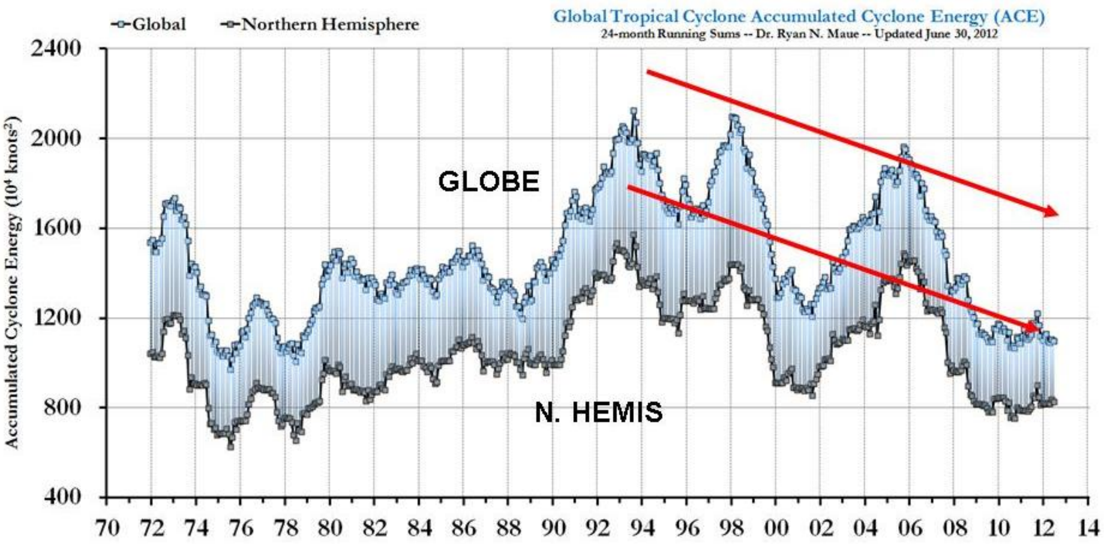


Figure 15: Northern Hemisphere and global Accumulated Cyclone Energy (ACE) over the period from December 1971-June 2012. Figure has been adapted from Ryan Maue.

Causes of the Upswing in Atlantic Major Hurricane Activity since 1995. The Atlantic Ocean has a strong multi-decadal signal in its hurricane activity which is likely due to multi-decadal variations in the strength of the THC (Figure 16). The oceanic and atmospheric response to the THC is often referred to as the Atlantic Multi-decadal Oscillation (AMO). We use the THC and AMO interchangeably throughout the remainder of this discussion. The strength of the THC can never be directly measured, but it can be diagnosed, as we have done, from the magnitude of the SST anomaly (SSTA) in the North Atlantic (Figure 17) combined with the sea level pressure anomaly (SLPA) in the Atlantic between the latitude of the equator and 50°N (Klotzbach and Gray 2008).

The THC (or AMO) is strong when there is an above-average poleward advection of warm low-latitude waters to the high latitudes of the North Atlantic. This water can then sink to deep levels when it reaches the far North Atlantic in a process known as deep water formation. The water then moves southward at deep levels in the ocean. The amount of North Atlantic water that sinks is proportional to the water's density which is determined by its salinity content as well as its temperature. Salty water is denser than fresh water at water temperatures near freezing. There is a strong association between North Atlantic SSTA and North Atlantic salinity (Figure 18). High salinity implies higher rates of North Atlantic deep water formation (or subsidence) and thus a stronger flow of upper level warm water from lower latitudes as replacement. See the papers by Gray et al. (1999), Goldenberg et al. (2001), and Grossmann and Klotzbach (2009) for more discussion.

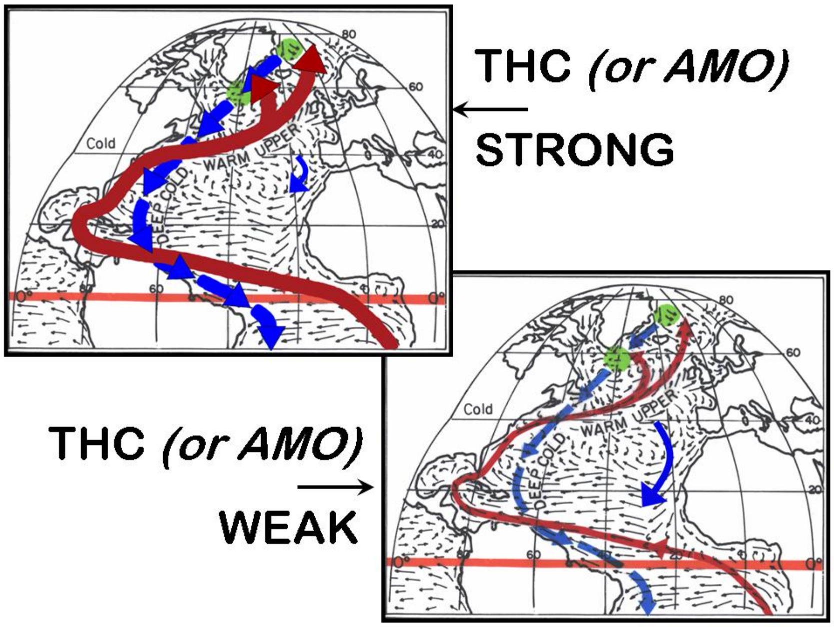


Figure 16: Illustration of strong (top) and weak (bottom) phases of the THC or AMO.

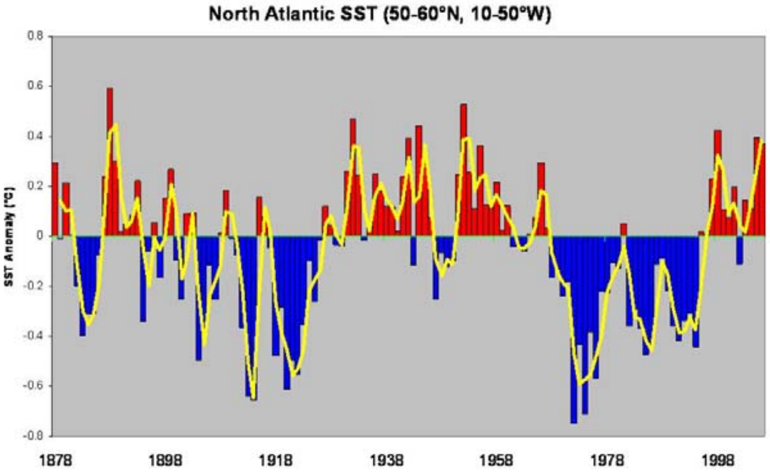


Figure 17: Long-period portrayal (1878-2006) of North Atlantic sea surface temperature anomalies (SSTA). The red (warm) periods are when the THC (or AMO) is stronger than average and the blue periods are when the THC (or AMO) is weaker than average.

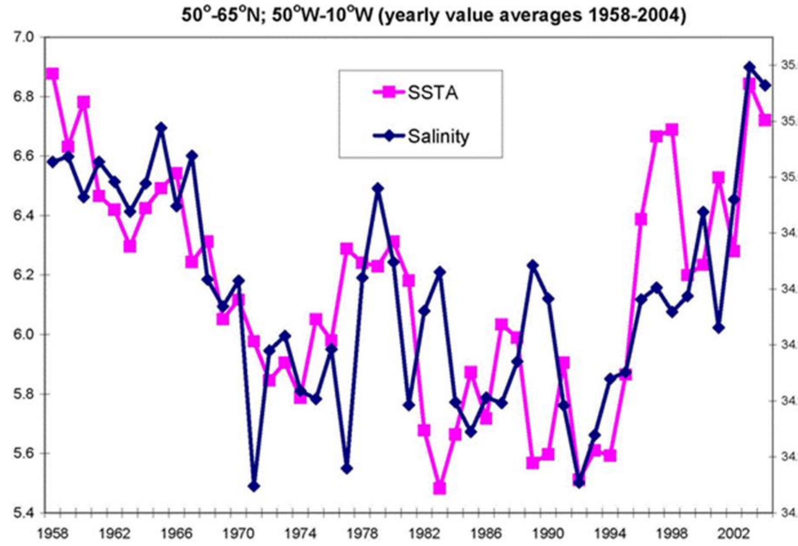


Figure 18: Illustration of the strong association of yearly average North Atlantic SSTA and North Atlantic salinity content between 1958 and 2004.

B. WHY CO_2 INCREASES ARE NOT RESPONSIBLE FOR ATLANTIC SST AND HURRICANE ACTIVITY INCREASES

Theoretical considerations do not support a close relationship between SSTs and hurricane intensity. In a global warming world, the atmosphere's upper air temperatures will warm or cool in unison with longer-period SST changes. Vertical lapse rates will thus not be significantly altered in a somewhat warmer or somewhat cooler tropical oceanic environment. We have no plausible physical reasons for believing that Atlantic hurricane frequency or intensity will significantly change if global or Atlantic Ocean temperatures were to rise by 1-2°C. Without corresponding changes in many other basic features, such as vertical wind shear or mid-level moisture, little or no additional TC activity should occur with SST increases.

Confusing Time Scales of SST Influences. A hurricane passing over a warmer body of water, such as the Gulf Stream, will often undergo some intensification. This is due to the sudden lapse rate increase which the hurricane's inner core experiences when it passes over warmer water. The warmer SSTs cause the hurricane's lower boundary layer temperature and moisture content to rise. While these low-level changes are occurring, upper tropospheric conditions are often not altered significantly. These rapidly occurring lower- and upper-level temperature differences cause the inner-core hurricane lapse rates to increase and produce more intense inner-core deep cumulus convection. This typically causes an increase in hurricane intensity. Such observations have led many observers to directly associate SST increases with greater hurricane potential intensity. This is valid reasoning for day-to-day hurricane intensity change associated with hurricanes moving over warmer or colder patches of SST. But such direct reasoning does not hold for conditions occurring in an overall climatologically warmer (or cooler) tropical oceanic environment where broad-scale global and tropical rainfall conditions are not expected to significantly vary. During long-period climate change, temperature and moisture conditions rise at both lower and upper levels. Lapse rates are little affected.

Any warming-induced increase in boundary layer temperature and moisture will be (to prevent significant global rainfall alteration) largely offset by a similar but weaker change through the deep troposphere up to about 10 km height. Upper-tropospheric changes are weaker than boundary layer changes, but they occur through a much deeper layer. These weaker and deeper compensating increases in upper-level temperature and moisture are necessary to balance out the larger increases in temperature and moisture which occur in the boundary layer. Global and tropical rainfall would be altered significantly only if broad-scale lapse rates were ever altered to an appreciable degree.

Thus, we cannot automatically assume that with warmer global SSTs that we will have more intense hurricanes due to lapse-rate alterations. We should not expect that the frequency and/or intensity of major hurricanes will necessarily change as a result of changes in global or individual storm basin SSTs. Historical evidence does not support hurricanes being less intense during the late 19th century and the early part of the 20th century when SSTs were lower than they are today.

C. DISCUSSION

We have no plausible physical reasons for believing that Atlantic hurricane frequency or intensity will change significantly if global ocean temperatures were to continue to rise. For instance, in the quarter-century period from 1945-1969 when the globe was undergoing a weak cooling trend, the Atlantic basin experienced 80 major (Cat 3-4-5) hurricanes and 201 major hurricane days. By contrast, in a similar 25-year period from 1970-1994 when the globe was undergoing a general warming trend, there were only 38 Atlantic major hurricanes (48% as many) and 63 major hurricane days (31% as many) (Figure 19). Atlantic SSTs and hurricane activity do not follow global mean temperature trends.

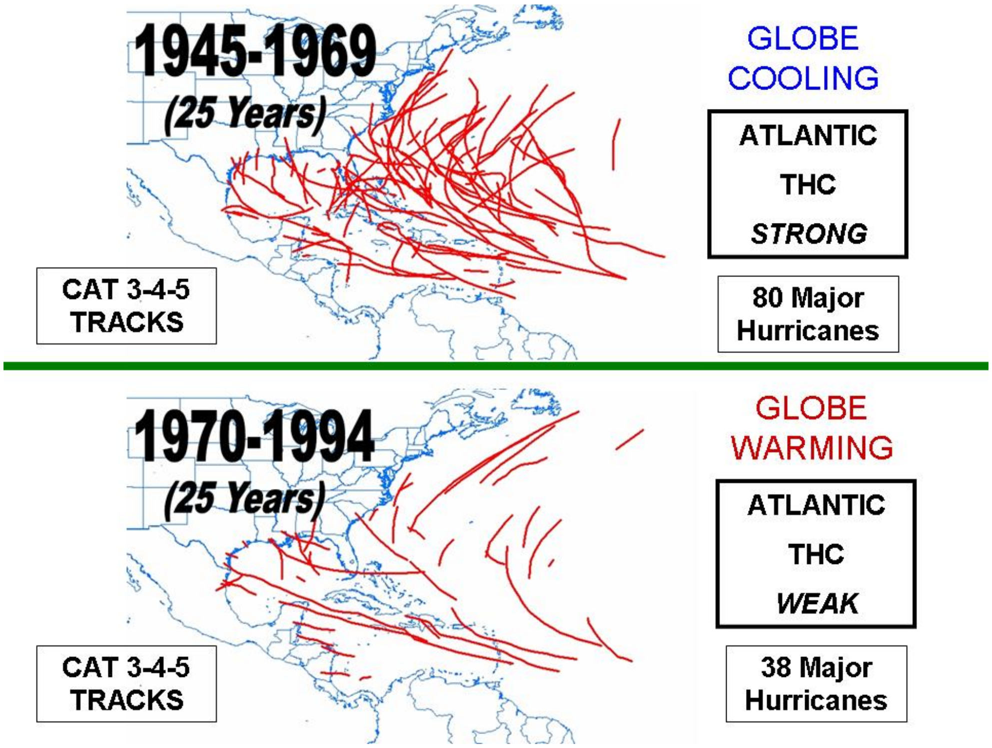


Figure 19: Tracks of major (Category 3-4-5) hurricanes during the 25-year period of 1945-1969 when the globe was undergoing a weak cooling versus the 25-year period of 1970-1994 when the globe was undergoing a modest warming. CO_2 amounts in the later period were approximately 18 percent higher than in the earlier period. Major Atlantic hurricane activity was less than half as frequent during the latter period despite warmer global temperatures.

The most reliable long-period hurricane records we have are the measurements of US landfalling TCs since 1900 (Table 12). Although global mean ocean and Atlantic SSTs have increased by about 0.4°C between the two 56-year periods (1900-1955 compared with 1956-2011), the frequency of US landfall numbers actually shows a slight downward trend for the later period. This downward trend is particularly noticeable for the US East Coast and Florida Peninsula where the difference in landfall of major (Category 3-4-5) hurricanes between the 46-year period of 1920-1965 (24 landfall events) and the 46-year period of 1966-2011 (7 landfall events) has been especially large (Figure 20). For the entire United States coastline, 39 major hurricanes made landfall during the earlier 46-year period (1920-1965) compared with only 26 major hurricanes for the latter 46-year period (1966-2011). This occurred despite the fact that CO_2 averaged approximately 365 ppm during the latter period compared with 310 ppm during the earlier period.

Table 13: U.S. landfalling tropical cyclones by intensity during two 56-year periods.

YEARS	***Named Storms***	***Hurricanes***	***Major Hurricanes (Cat 3-4-5)***	***Global Temperature Increase***
1900-1955 (56 years)	213	116	45	+0.4°C
1956-2011 (56 years)	182	88	34	

We should not read too much into the four very active hurricane seasons of 2004, 2005, 2008 and 2010. The activity of these years was unusual but well within natural bounds of hurricane variation.

What made the 2004, 2005 and 2008 seasons so destructive was not the high frequency of major hurricanes but the high percentage of hurricanes that were steered over the US coastline. The US hurricane landfall events of these years were primarily a result of the favorable upper-air steering currents present during these years.

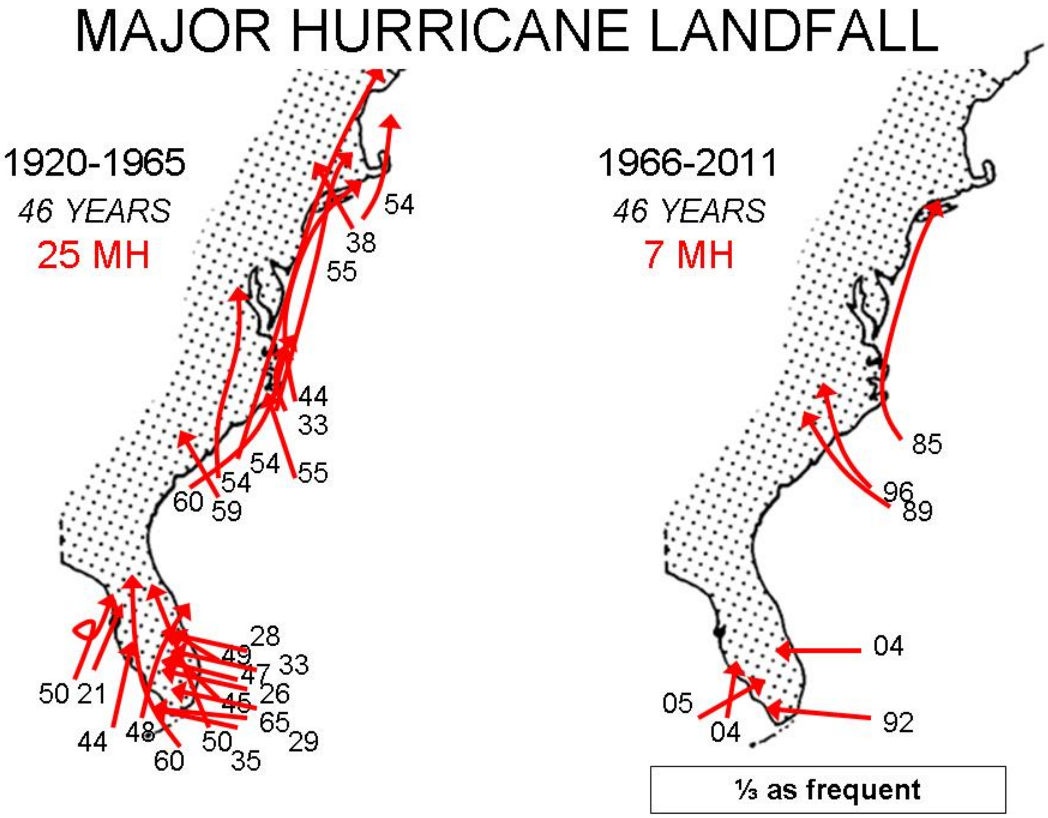


Figure 20: Contrast of tracks of East Coast and Florida Peninsula major landfalling hurricanes during the 46-year period of 1920-1965 versus the most recent 46-year period of 1966-2011.

Although 2005 had a record number of TCs (28 named storms), this should not be taken as an indication of something beyond natural processes. There have been several other years with comparable hurricane activity to 2005. For instance, 1933 had 20 named storms in a year when there was no satellite or aircraft data. Records of 1933 show all 20 named storms had tracks west of 60°W where surface observations were more plentiful. If we eliminate all of the named storms of 2005 whose tracks were entirely east of 60°W and therefore may have been missed given the technology available in 1933, we reduce the 2005 named storm total by seven (to 21) – one more than the number observed in 1933.

Utilizing the National Hurricane Center's best track database of hurricane records back to 1875, six previous seasons had more hurricane days than the 2005 season. These years were 1878, 1893, 1926, 1933, 1950 and 1995. Also, five prior seasons (1893, 1926, 1950, 1961 and 2004) had more major hurricane days. Although the 2005 hurricane season was certainly one of the most active on record, it was not as much of an outlier as many have indicated.

We believe that the Atlantic basin remains in an active hurricane cycle associated with a strong THC. This active cycle is expected to continue for another decade or two at which time we should enter a quieter Atlantic major hurricane period like we experienced during the quarter-century periods of 1970-1994 and 1901-1925. Atlantic hurricanes go through multi-decadal cycles. Cycles in Atlantic major hurricanes have been observationally traced back to the mid-19th century. Changes in the THC (or AMO) have been inferred from Greenland paleo ice-core temperature measurements going back thousands of years. These changes are natural and have nothing to do with human activity.

11 Forthcoming Updated Forecasts of 2012 Hurricane Activity

We will be issuing two-week forecasts for Atlantic TC activity during the climatological peak of the season from August-October. The first of these forecasts will be issued in a companion document today (August 3). Additional two-week forecasts will be issued every other Friday (e.g., August 17, August 31, etc.) The full schedule of two-week forecasts is available here: http://tropical.atmos.colostate.edu/Includes/Documents/Two_Week_Forecasts.html.

An October-November outlook for the Caribbean will be issued on 1 October. A verification and discussion of all 2012 forecasts will be issued in late November 2012. All of these forecasts will be available on the web at: http://hurricane.atmos.colostate.edu/Forecasts.

12 Acknowledgments

Besides the individuals named on page 5, there have been a number of other meteorologists that have furnished us with data and given valuable assessments of the current state of global atmospheric and oceanic conditions. These include Brian McNoldy, Art Douglas, Ray Zehr, Mark DeMaria, Dave Masonis, Todd Kimberlain, Paul Roundy, Amato Evan and Jason Dunion. In addition, Barbara Brumit and Amie Hedstrom have provided excellent manuscript, graphical and data analysis and assistance over a number of years. We gratefully acknowledge support from former project members and colleagues Ken Berry, Paul Mielke, Chris Landsea, John Knaff, Eric Blake and Bill Thorson.

We have profited over the years from many in-depth discussions with most of the current and past NHC hurricane forecasters. The second author would further like to acknowledge the encouragement he has received for this type of forecasting research application from Neil Frank, Robert Sheets, Robert Burpee, Jerry Jarrell, Max Mayfield and Bill Read, former directors of the National Hurricane Center (NHC). We look forward to future exchanges with the new NHC director Rick Knabb.

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14 Verification of Previous Forecasts

Table 13: Summary verification of the authors' four previous years of seasonal forecasts for Atlantic TC activity between 2008-2011. Verifications of all seasonal forecasts back to 1984 are available here: http://tropical.atmos.colostate.edu/Includes/Documents/Publications/forecast_verifications.xls

2008	7 Dec. 2007	Update 9 April	Update 3 June	Update 5 August	Obs.
Hurricanes	7	8	8	9	8
Named Storms	13	15	15	17	16
Hurricane Days	30	40	40	45	30.50
Named Storm Days	60	80	80	90	88.25
Major Hurricanes	3	4	4	5	5
Major Hurricane Days	6	9	9	11	7.50
Accumulated Cyclone Energy	115	150	150	175	146
Net Tropical Cyclone Activity	125	160	160	190	162

2009	10 Dec. 2008	Update 9 April	Update 2 June	Update 4 August	Obs.
Hurricanes	7	6	5	4	3
Named Storms	14	12	11	10	9
Hurricane Days	30	25	20	18	12
Named Storm Days	70	55	50	45	30
Major Hurricanes	3	2	2	2	2
Major Hurricane Days	7	5	4	4	3.50
Accumulated Cyclone Energy	125	100	85	80	53
Net Tropical Cyclone Activity	135	105	90	85	69

2010	9 Dec. 2009	Update 7 April	Update 2 June	Update 4 August	Obs.
Hurricanes	6-8	8	10	10	12
Named Storms	11-16	15	18	18	19
Hurricane Days	24-39	35	40	40	38.50
Named Storm Days	51-75	75	90	90	89.50
Major Hurricanes	3-5	4	5	5	5
Major Hurricane Days	6-12	10	13	13	11
Accumulated Cyclone Energy	100-162	150	185	185	165
Net Tropical Cyclone Activity	108-172	160	195	195	196

2011	8 Dec. 2010	Update 6 April	Update 1 June	Update 3 August	Obs.
Hurricanes	9	9	9	9	7
Named Storms	17	16	16	16	19
Hurricane Days	40	35	35	35	26
Named Storm Days	85	80	80	80	89.75
Major Hurricanes	5	5	5	5	4
Major Hurricane Days	10	10	10	10	4.5
Accumulated Cyclone Energy	165	160	160	160	126
Net Tropical Cyclone Activity	180	175	175	175	145

Comment: We are proud of the success of the last four years of our seasonal forecasts. Our forecasts from early April, June and August have shown significant skill over climatology as well as the previous five-year mean

As forecasters, we, of course, fully realize the old adage:

"If you forecast wrong, nobody will forget it; if you forecast right, nobody will remember it."