FORECAST OF ATLANTIC SEASONAL HURRICANE ACTIVITY AND LANDFALL STRIKE PROBABILITY FOR 2010

We have maintained our forecast from early June and continue to call for a very active Atlantic basin hurricane season in 2010 due to unusually warm tropical Atlantic sea surface temperatures and the development of La Niña. We anticipate a well above-average probability of United States and Caribbean major hurricane landfall.

(as of 4 August 2010)

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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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 it regards to the probability of an active or inactive hurricane season. Our early August statistical forecast methodology shows strong evidence over more than 100 past years that significant improvement over climatology can be attained. We would never issue a seasonal hurricane forecast unless we had a statistical model developed 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 an 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. However, all coastal residents should prepare for an active hurricane season every year. Landfalling tropical cyclones can devastate communities in inactive or active seasons. It only takes one landfalling system to make this a very active season for you.

ATLANTIC BASIN SEASONAL HURRICANE FORECAST FOR 2010

Forecast Parameter and 1950-2000 Climatology (in parentheses)	Issue Date 9 December 2009	Issue Date 7 April 2010	Issue Date 2 June 2010	Observed Activity Through July 2010	Forecast Activity After 31 July	Total Seasonal Forecast
Named Storms (NS) (9.6)	11-16	15	18	2	16	18
Named Storm Days (NSD) (49.1)	51-75	75	90	5.75	84.25	90
Hurricanes (H) (5.9)	6-8	8	10	1	9	10
Hurricane Days (HD) (24.5)	24-39	35	40	1.50	38.50	40
Major Hurricanes (MH) (2.3)	3-5	4	5	0	5	5
Major Hurricane Days (MHD) (5.0)	6-12	10	13	0	13	13
Accumulated Cyclone Energy (ACE) (96.1)	100-162	150	185	7	178	185
Net Tropical Cyclone Activity (NTC) (100%)	108-172	160	195	9	186	195

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 - 75% (average for last century is 52%)

2) U.S. East Coast Including Peninsula Florida - 50% (average for last century is 31%)

3) Gulf Coast from the Florida Panhandle westward to Brownsville - 49% (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) 64% (average for last century is 42%)

ABSTRACT

Information obtained through July 2010 indicates that the 2010 Atlantic hurricane season will be much more active than the average 1950-2000 season. We estimate that 2010 will have about 10 hurricanes (average is 5.9), 18 named storms (average is 9.6), 90 named storm days (average is 49.1), 40 hurricane days (average is 24.5), 5 major (Category 3-4-5) hurricanes (average is 2.3) and 13 major hurricane days (average is 5.0). The probability of U.S. major hurricane landfall and Caribbean major hurricane activity is estimated to be well above its long-period average. We expect Atlantic basin Net Tropical Cyclone (NTC) activity in 2010 to be approximately 195 percent of the long-term average season. We have maintained our seasonal forecast from early June.

This forecast is based on an extended-range early August statistical prediction scheme that utilizes over 100 years of past data. Analog predictors are also utilized. The influence of El Niño conditions is implicit in these predictor fields, and therefore we do not utilize a specific ENSO forecast as a predictor.

We have witnessed the development of La Niña conditions over the past couple of months, and we believe that a moderate La Niña will be present over the next several months. The trend towards La Niña conditions should lead to reduced levels of vertical wind shear compared with what was witnessed in 2009. Another reason for our continued active seasonal forecast is due to the persistence of anomalously warm sea surface temperatures in both the tropical and North Atlantic. Current SST anomalies in the tropical Atlantic remain at near-record warm levels. These very warm waters are associated with dynamic and thermodynamic factors that are very conducive for an active Atlantic hurricane season. Another factor in the maintenance of our very active season forecast is the anomalously low sea level pressures that have occurred across the tropical Atlantic in June and July. Anomalously low pressure typically results in weaker trade winds that are commonly associated with more active hurricane seasons. Another important factor is that we are in the midst of a multi-decadal era of more major hurricane activity. Major hurricanes cause 80-85 percent of normalized hurricane damage.

We are also now issuing a hurricane forecast for activity in the Caribbean Basin. This forecast is based on a statistical prediction scheme that utilizes 60 years of past data. This model is predicting a very active season for the Caribbean.

How will the Gulf oil spill impact a hurricane?

We do not anticipate that the oil spill will have any noticeable impact on tropical cyclone intensity or frequency. The strong winds of a tropical storm or hurricane should sufficiently mix the oil and water that there should be no noticeable alterations in broad-scale evaporation and sensible and latent heat flux.

What impact will a hurricane have on the Gulf oil spill?

This depends on the storm's track in relation to the oil spill. If the storm tracks to the west of the oil, there is the potential that the counter-clockwise circulation of the hurricane could drive some of the oil further towards the U.S. Gulf Coast. Alternatively, a storm tracking to the east of the oil could push the oil further offshore. But, little is understood about the interaction of tropical cyclones and oil.

Notice of Author Changes

By William Gray

The order of the authorship of these forecasts was reversed in 2006 from Gray and Klotzbach to Klotzbach and Gray. After 22 years (1984-2005) of making these forecasts, it was appropriate that I step back and have Phil Klotzbach assume the primary responsibility for our project's seasonal forecasts. Phil has been a member of my research project for the last ten years and was second author on these forecasts from 2001-2005. I have greatly profited and enjoyed our close personal and working relationship.

Phil is now devoting much more time to the improvement of these forecasts than I am. I am now giving more of my efforts to the global warming issue and in synthesizing my projects' many years of hurricane and typhoon studies.

Phil Klotzbach is an outstanding young scientist with a superb academic record. I have been amazed at how far he has come in his knowledge of hurricane prediction since joining my project in 2000. I foresee an outstanding future for him in the hurricane field. He is currently developing new seasonal and two-week forecast innovations that are improving our forecasts. The success of the last two years of seasonal forecasts is an example. Phil was awarded his Ph.D. degree in 2007. He is currently spending most of his time working towards better understanding and improving these Atlantic basin hurricane forecasts.

Acknowledgment

We are grateful to the National Science Foundation (NSF) for providing partial support for the research necessary to make these forecasts. We also thank the GeoGraphics Laboratory at Bridgewater State College (MA) for their assistance in developing the United States Landfalling Hurricane Probability Webpage (available online at http://www.e-transit.org/hurricane).

The second author gratefully acknowledges the valuable input to his CSU seasonal forecast research project over many years by former project members and now colleagues Chris Landsea, John Knaff and Eric Blake. We also thank Professors Paul Mielke and Ken Berry of Colorado State University for much statistical analysis and advice over many years. We also thank Bill Thorson for technical advice and assistance.

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.

Atlantic Multi-Decadal Oscillation (AMO) – A mode of natural variability that occurs in the North Atlantic Ocean and evidencing itself in fluctuations in both sea surface temperature and sea level pressure fields. The AMO is likely related to fluctuations in the strength of the 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 approximately 40-50 days.

Main Development Region (MDR) – An area in the tropical Atlantic where a majority of major hurricanes form, defined 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 Scale – A measurement scale ranging from 1 to 5 of hurricane wind and ocean surge 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.

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.

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 (18 ms^{-1} or 34 knots) and 73 (32 ms^{-1} or 63 knots) miles per hour.

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 27th 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. Our early August forecast is based on a statistical methodology derived from over 100 years of past data. 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 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 that 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 2-3 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 2010 Atlantic Basin Activity through July

The 2010 Atlantic basin hurricane season had approximately average tropical cyclone activity, based on the ACE index, during June and July. Hurricane Alex formed on June 26 and made its first landfall in Belize the following day. After briefly weakening to a tropical depression, Alex reintensified into a tropical storm and then to a hurricane as it tracked through the southern Gulf of Mexico. Alex made landfall late on June 30 approximately 100 miles south of Brownsville, Texas. Alex was the strongest June hurricane in terms of maximum sustained winds since Alma (1966).

Bonnie formed in the Bahamas on July 22 and briefly strengthened to a minimal tropical storm despite being buffeted by strong vertical wind shear from a cold low to its west. It made landfall as a 35-knot storm in southeast Florida before dissipating, due to persistent shear, as it emerged over the Gulf of Mexico.

Table 1 records observed Atlantic basin tropical cyclone activity through 31 July, while tracks through 31 July are displayed in Figure 1.

Table 1: Observed 2010 Atlantic basin tropical cyclone activity through July.

Highest Category	Name	Dates	Peak Sustained Winds (kts)/lowest SLP (mb)	NSD	HD	IHD	ACE	NTC
H-2	Alex	June 26 – July 1	90 kt/947 mb	5.00	1.50		6.7	7.3
TS	Bonnie	July 22 – July 23	35 kt/1006 mb	0.75			0.3	2.0
Totals	2			5.75	1.50		7.0	9.3

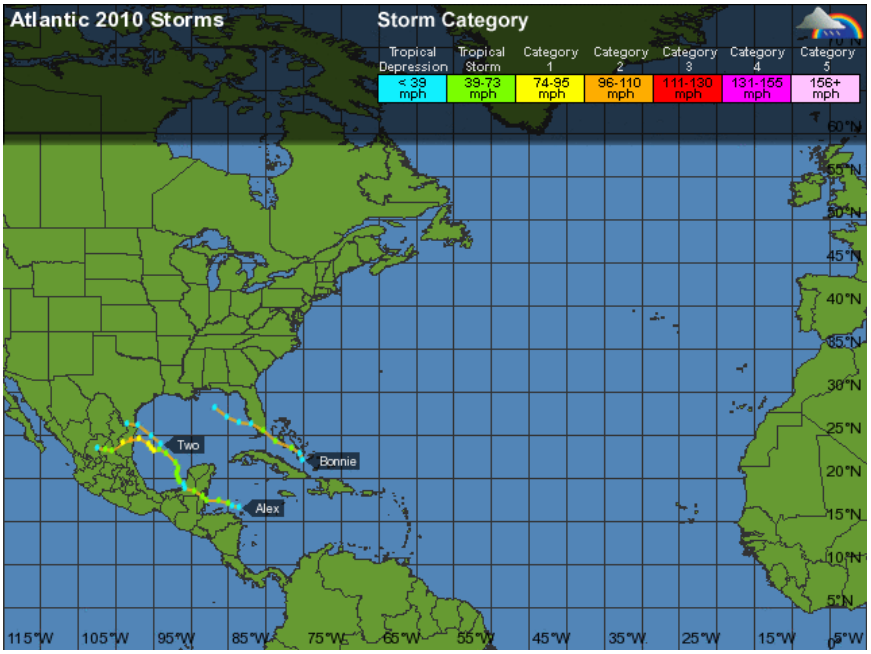


Figure 1: 2010 Atlantic basin hurricane tracks through July. Figure courtesy of Weather Underground (http://www.weatherunderground.com).

2 Newly-Developed 1 August Forecast Scheme

We have recently developed a new 1 August statistical seasonal forecast scheme for the prediction of Net Tropical Cyclone (NTC) activity. This scheme was developed on NCEP/NCAR reanalysis data from 1949-1989. It was then tested on independent data from 1990-2005 to insure that the forecast showed similar skill in this later period. As a rule, predictors were only added to the scheme if they explained an additional three percent of the variance of NTC in both the dependent period (1949-1989) and the independent period (1990-2005). The forecast scheme was also tested on independent data from 1900-1948. It showed comparable skill during this period. Over the 1900-1948 period, the scheme explained 51% of the variance in NTC activity, and over the more recent period from 1949-2009 the scheme also explained 51% of the variance.

The pool of four June-July predictors for the early August forecast is given and defined in Table 2. The location of each of these predictors is shown in Figure 2. Strong statistical relationships can be extracted via combinations of these predictive parameters (which are available by the end of July), and quite skillful Atlantic basin forecasts of NTC activity for the season can be made if the atmosphere and ocean continue to behave in the future as they have in the recent past.

This scheme only predicts Net Tropical Cyclone (NTC) activity, and the other seasonal predictors are then derived from this NTC prediction. These other seasonal predictors are calculated by taking the observed historical relationships between themselves and NTC. Relationships between NTC and other seasonal metrics such as named storms, named storm days and hurricane days were derived by breaking up the observed hurricane statistics from 1950-2007 into six groups based on NTC ranking. Equations for converting NTC to other seasonal parameters were then calculated by fitting a least squared regression equation to the observed data. These equations are listed below. Figure 3 illustrates predictions for various seasonal parameters given NTC values of 150, 100 and 50, respectively. Utilizing this approach gives slightly lower root mean squared errors and seems more physically appropriate than simply adjusting each seasonal parameter by a uniform NTC factor.

Named Storms = 5.0 + (0.049 * NTC)
Named Storm Days = 10.5 + (0.375 * NTC)
Hurricanes = 2.2 + (0.036 * NTC)
Hurricane Days = -0.6 + (0.231 * NTC)
Major Hurricanes = -0.7 + (0.031 * NTC)
Major Hurricane Days = -3.8 + (0.092 * NTC)
Accumulated Cyclone Energy = -6.6 + (0.978 * NTC)

Table 2: Listing of 1 August 2010 predictors for this year's hurricane activity. 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 four predictors calls for an above-average hurricane season.

Predictor	Values for 2010 Forecast	Effect on 2010 Hurricane Season
1) June-July SST (20-40°N, 15-35°W) (+)	0.0 SD	Neutral
2) June-July SLP (10-25°N, 10-60°W) (-)	-1.0 SD	**Enhance**
3) June-July SST (5°S-5°N, 90-150°W) (-)	-0.9 SD	**Enhance**
4) Pre-1 August Named Storm Days – South of 23.5°N, East of 75°W (+)	0 NSD	Suppress

Post-1 August Seasonal Forecast Predictors

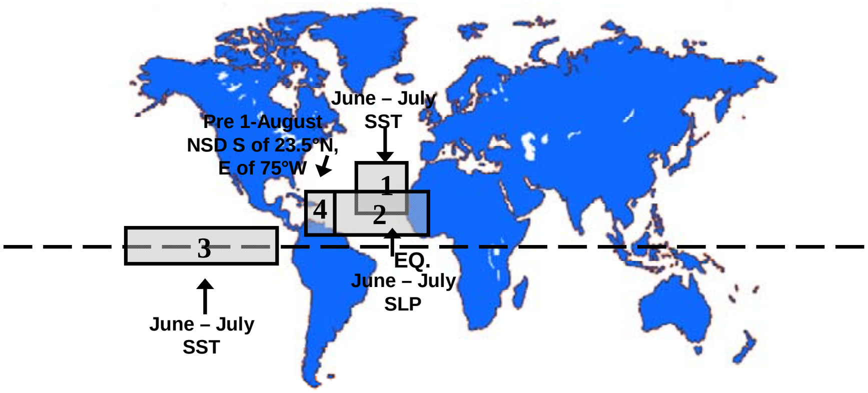


Figure 2: Location of predictors for the post-31 July forecast for the 2010 hurricane season.

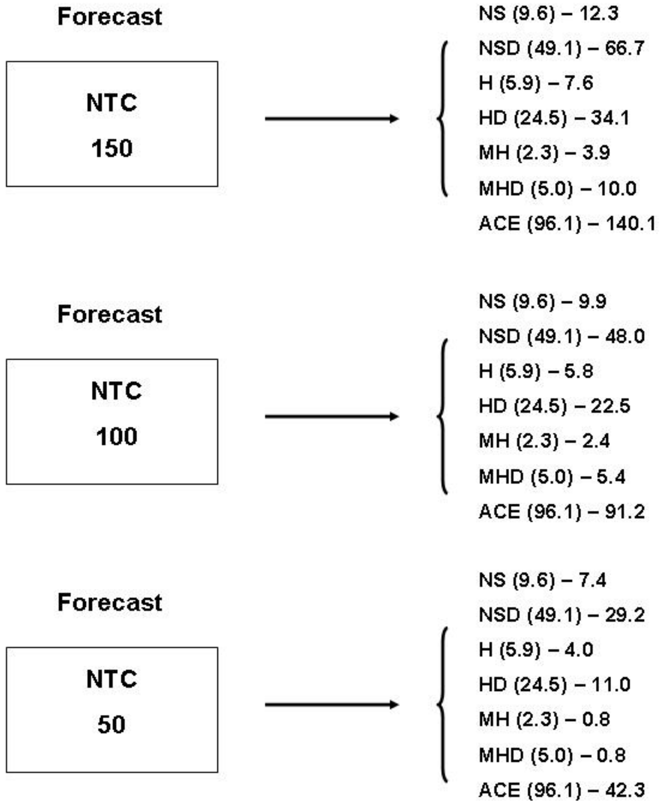


Figure 3: Schematic showing how predictions of 150, 100 and 50 NTC units, respectively, would be converted into predictions for other seasonal parameters. Numbers in parentheses are the climatological averages.

Table 3 shows our statistical forecast for the 2010 hurricane season and the comparison of this forecast with climatology (average season from 1950-2000). Our statistical forecast is calling for above-average activity this year.

Table 3: Post-31 July statistical forecast for 2010.

Predictands and Climatology (1950-2000 – Post-31 July Average)	Statistical Forecast
Named Storms (NS) – 8.4	11.1
Named Storm Days (NSD) – 44.9	57.7
Hurricanes (H) – 5.4	6.7
Hurricane Days (HD) – 23.4	28.5
Major Hurricanes (MH) – 2.1	3.2
Major Hurricane Days (MHD) – 4.9	7.8
Accumulated Cyclone Energy Index (ACE) – 90	117
Net Tropical Cyclone Activity (NTC) – 93	126

Table 4 displays our early August hindcasts for 1949-2005 using the new statistical scheme, along with real-time forecasts from the statistical model for 2006-2009, while Figure 4 displays observations versus NTC hindcasts/forecasts. Our early August model has correctly predicted above- or below-average post-1 August NTC in 51 out of 61 years (84%). These hindcasts have had a smaller error than climatology in 46 out of 61 years (75%). Our average hindcast errors have been 29 NTC units, compared with 43 NTC units had we used only climatology. This new scheme is also well-tuned to the multi-decadal active hurricane periods from 1950-1969 and 1995-2009 versus the inactive hurricane period from 1970-1994 (Table 5).

Table 4: Observed versus hindcast post-1 August NTC for 1949-2009 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 51 out of 61 years (84%), while hindcast improvement over climatology occurred in 46 out of 61 years (75%). Note that since 1977, this forecast scheme has beaten climatology in all but four years.

Year	Observed NTC	Hindcast NTC	Observed minus Hindcast	Observed minus Climatology	Hindcast improvement over Climatology
1949	117	139	-21	24	3
1950	247	129	118	154	36
1951	127	142	-15	34	19
1952	101	145	-44	8	**-36**
1953	125	121	4	32	28
1954	115	118	-3	22	19
1955	205	179	27	112	86
1956	60	89	-29	-33	4
1957	67	**101**	-33	-26	**-8**
1958	142	113	29	49	20
1959	73	**105**	-32	-20	**-12**
1960	79	**169**	-90	-14	**-76**
1961	209	159	50	116	66
1962	41	**117**	-76	-52	**-24**
1963	116	107	10	23	14
1964	179	137	42	86	44
1965	83	60	23	-10	**-14**
1966	96	163	-66	3	**-63**
1967	102	101	1	9	8
1968	32	81	-49	-61	12
1969	179	122	57	86	29
1970	56	85	-29	-37	8
1971	89	61	27	-4	**-23**
1972	26	26	-1	-67	67
1973	43	**103**	-60	-50	**-10**
1974	78	75	3	-15	11
1975	82	**114**	-32	-11	**-21**
1976	81	61	20	-12	**-8**
1977	47	89	-41	-46	4
1978	80	76	4	-13	8
1979	86	87	-1	-7	6
1980	130	103	28	37	10
1981	108	104	4	15	11
1982	30	30	0	-63	63
1983	31	43	-13	-62	50
1984	80	80	1	-13	12
1985	97	95	3	4	2
1986	28	39	-11	-65	54
1987	46	88	-42	-47	5
1988	117	133	-16	24	8
1989	123	152	-29	30	1
1990	90	**131**	-41	-3	**-38**
1991	55	75	-19	-38	18
1992	65	49	16	-28	13
1993	50	43	6	-43	37
1994	33	50	-17	-60	43
1995	205	203	2	112	110
1996	163	133	31	70	40
1997	33	46	-13	-60	47
1998	166	145	21	73	52
1999	178	126	52	85	33
2000	134	98	36	41	5
2001	133	117	16	40	24
2002	81	38	43	-12	**-31**
2003	155	138	17	62	45
2004	232	118	114	139	25
2005	204	184	20	111	91
2006	77	92	-15	-16	1
2007	92	**105**	-12	-1	**-12**
2008	125	191	-66	32	**-34**
2009	69	87	-19	-24	6
Average	**103**	**105**	**|29|**	**|43|**	**+14**

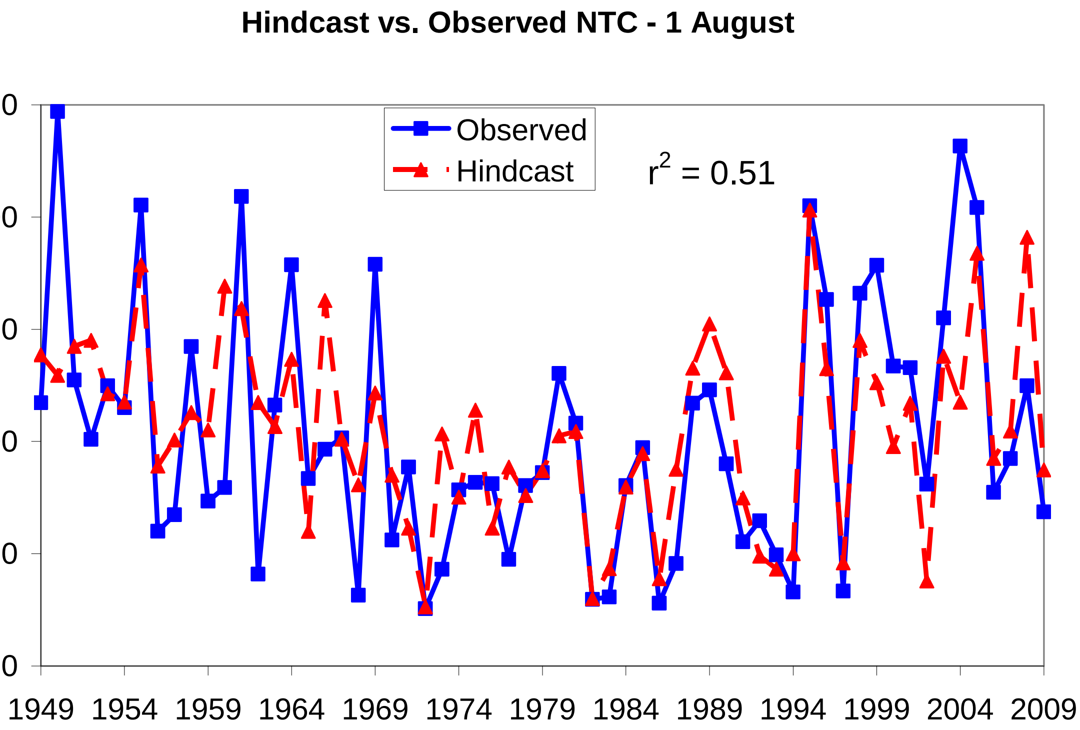


Figure 4: Observed versus hindcast values of post-31 July NTC for 1949-2009.

Table 5: Observed versus hindcast average post-31 July NTC for active vs. inactive multi-decadal periods.

Years	***Average Observed NTC***	***Average Hindcast NTC***
1949-1969 (Active)	119	124
1970-1994 (Inactive)	70	80
1995-2009 (Active)	137	121

2.1 Physical Associations among Predictors Listed in Table 2

The locations and brief descriptions of our four predictors for our 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 hurricane 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 sea surface temperature, sea level pressure, 925 mb zonal wind, and 200 mb zonal wind, respectively.

Predictor 1. June-July SST in the Northeastern Subtropical Atlantic (+)

(20°-40°N, 15-35°W)

Warm sea surface temperatures in this area in June-July correlate very strongly with anomalously warm sea surface temperatures in the tropical Atlantic throughout the upcoming hurricane season (Figure 5). Anomalously warm sea surface temperatures are important for development and intensification of tropical cyclones by infusing more latent heat into the system (Goldenberg and Shapiro 1998). In addition, associated with anomalously warm June-July SSTS are weaker trade winds. Weaker trade winds cause less evaporation and upwelling of cooler sub-surface water which feeds back into keeping the tropical Atlantic warm. In addition, weaker trade winds imply that there is less vertical wind shear across the tropical Atlantic. Weak wind shear is favorable for tropical cyclone development and intensification (Gray 1968, Gray 1984a, Goldenberg and Shapiro 1996, Knaff et al. 2004). Lastly, there is a strong positive correlation (~0.5) between anomalously warm June-July SSTs in the subtropical northeastern Atlantic and low sea level pressures in the tropical Atlantic and Caribbean during August-October. Low sea level pressures imply decreased subsidence and enhanced mid-level moisture. Both of these conditions are favorable for tropical cyclogenesis and intensification (Knaff 1997).

Predictor 2. June-July SLP in the Tropical Atlantic (-)

(10-25°N, 10-60°W)

Low sea level pressure in the tropical Atlantic in June-July implies that early summer conditions in the tropical Atlantic are favorable for an active tropical cyclone season with increased vertical motion, decreased stability and enhanced mid-level moisture. There is a strong auto-correlation ($r > 0.5$) between June-July sea level pressure anomalies and August-October sea level pressure anomalies in the tropical Atlantic (Figure 6). Low sea level pressure in the tropical Atlantic also correlates quite strongly ($r > 0.5$) with reduced trade winds (weaker easterlies) and anomalous easterly upper-level winds (weaker westerlies). The combination of these two features implies weaker vertical wind shear and therefore more favorable conditions for tropical cyclone development in the Atlantic (Gray 1968, Gray 1984a, Goldenberg and Shapiro 1996).

Predictor 3. June-July Nino3 Index (-)

(5°S-5°N, 90-150°W)

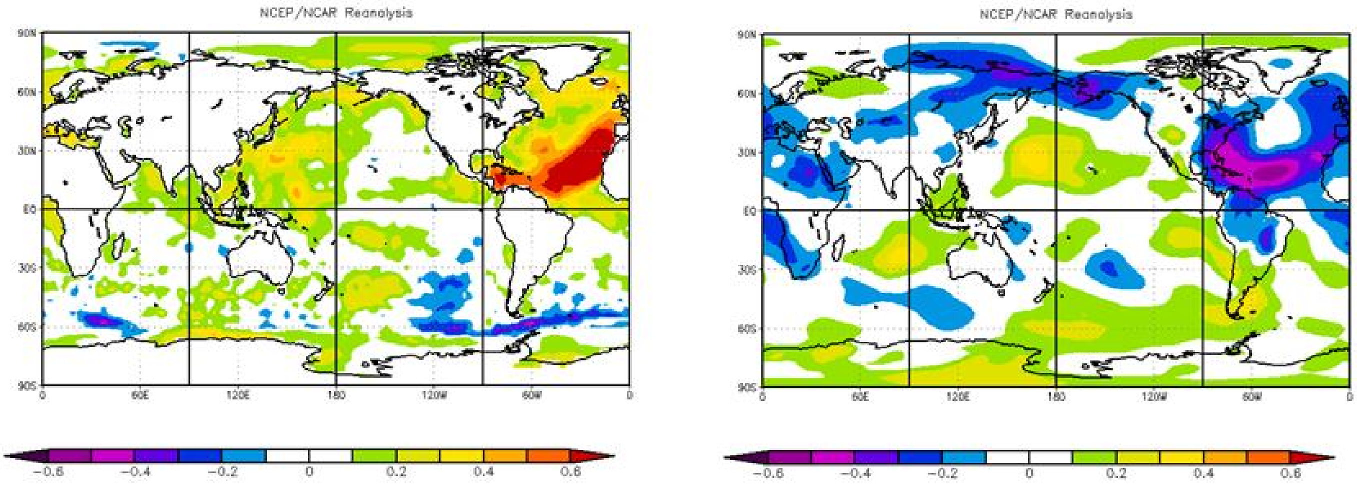
Cool sea surface temperatures in the Nino3 region during June-July imply that a La Niña event is currently present. In general, positive or negative anomalies in the Nino3 region during the early summer persist throughout the remainder of the summer and fall (Figure

7). El Niño conditions shift the center of the Walker Circulation eastward which causes increased convection over the central and eastern tropical Pacific. This increased convection in the central and eastern Pacific manifests itself in anomalous upper-level westerlies across the Caribbean and tropical Atlantic, thereby increasing vertical wind shear and reducing Atlantic basin hurricane activity. The relationship between ENSO and Atlantic hurricane activity has been well-documented in the literature (e.g., Gray 1984a, Goldenberg and Shapiro 1996, Elsner 2003, Bell and Chelliah 2006).

Predictor 4. Named Storm Days South of 23.5°N, East of 75°W (+)

Most years do not have named storm formations in June and July in the tropical Atlantic (south of 23.5°N); however, if tropical formations do occur, it indicates that a very active hurricane season is likely. For example, the seven years with the most named storm days in the deep tropics in June and July (since 1949) are 1966, 1969, 1995, 1996, 1998, 2005, and 2008. All seven of these seasons were very active. When storms form in the deep tropics in the early part of the hurricane season, it indicates that conditions are already very favorable for TC development. In general, the start of the hurricane season is restricted by thermodynamics (warm SSTs, unstable lapse rates), and therefore deep tropical activity early in the hurricane season implies that the thermodynamics are already quite favorable for TC development (Figure 8). Also, this predictor’s correlation with seasonal NTC is 0.52 over the 1950-2007 period, and when tested on independent data (1900-1948), the correlation actually improves to 0.63, which gives us increased confidence in its use as a seasonal predictor.

(a) SST (b) SLP



(c) 925 mb U (d) 200 mb U

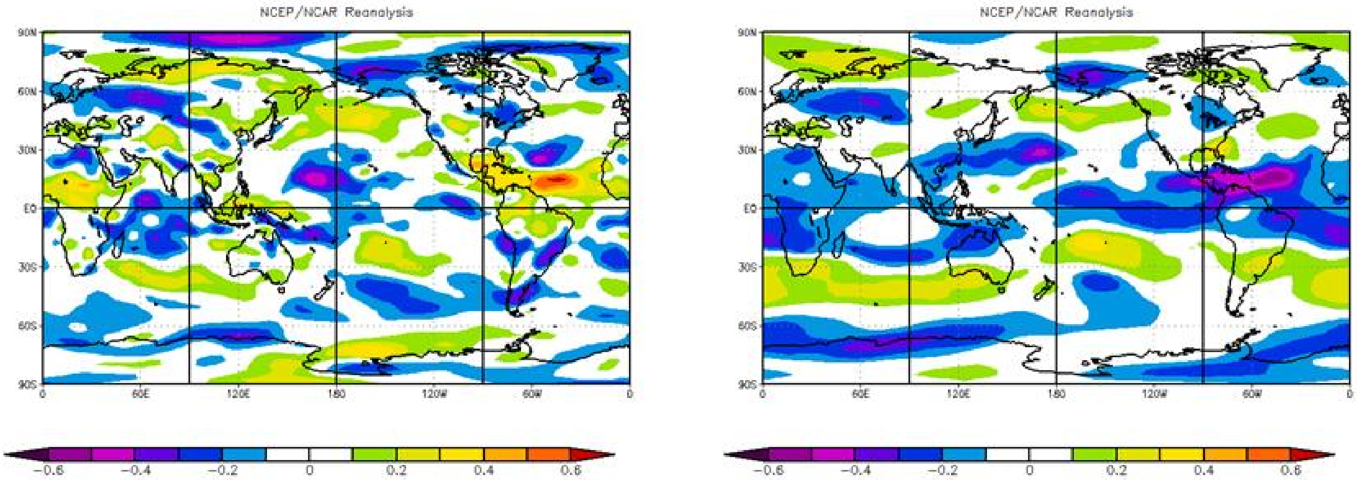


Figure 5: Linear correlations between June-July SST in the subtropical eastern Atlantic (Predictor 1) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d).

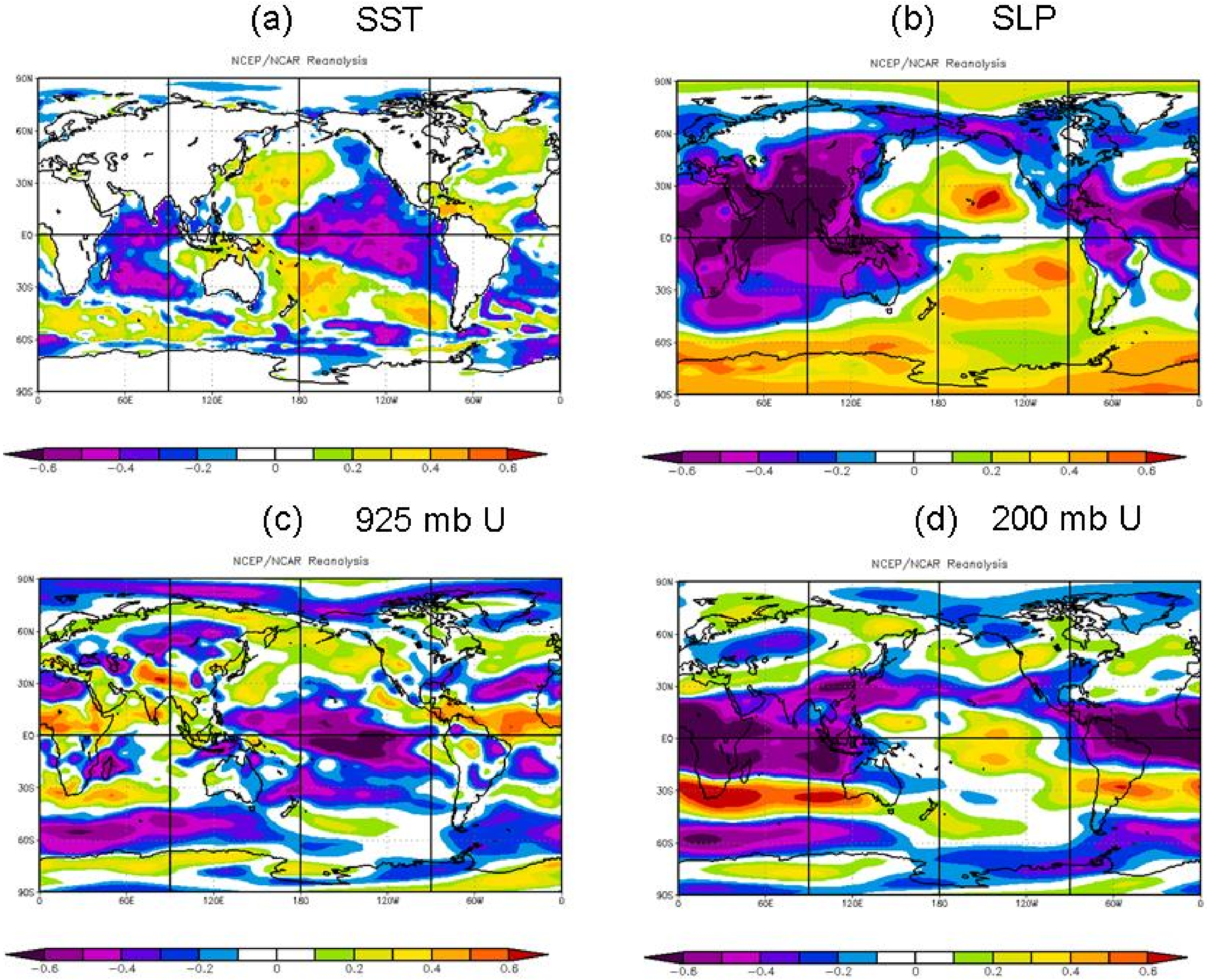
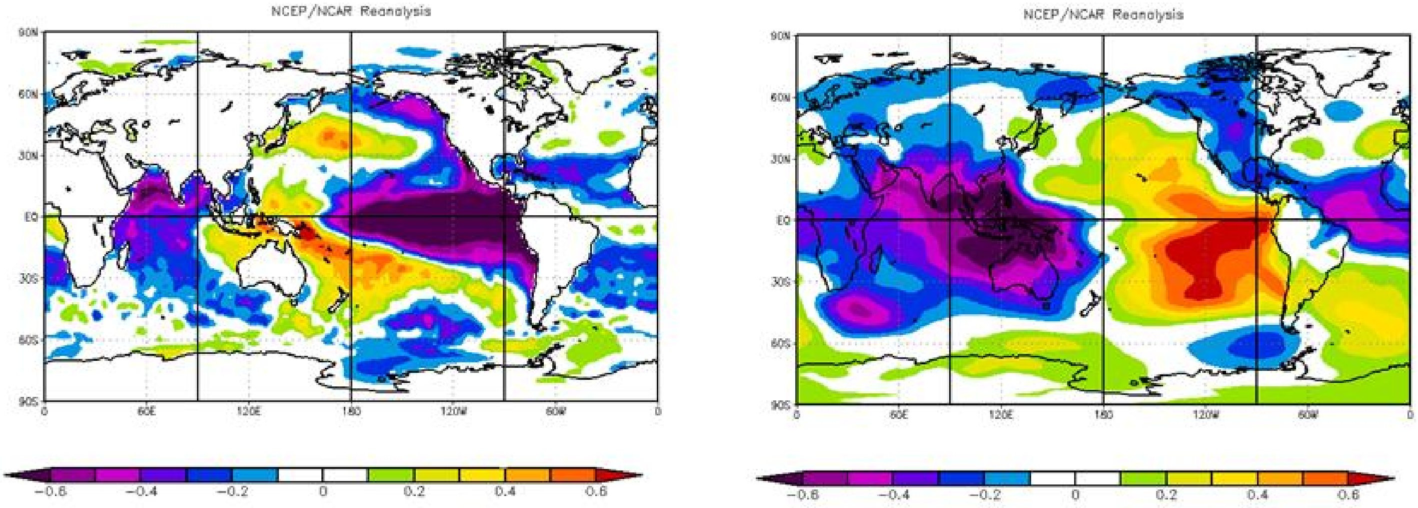
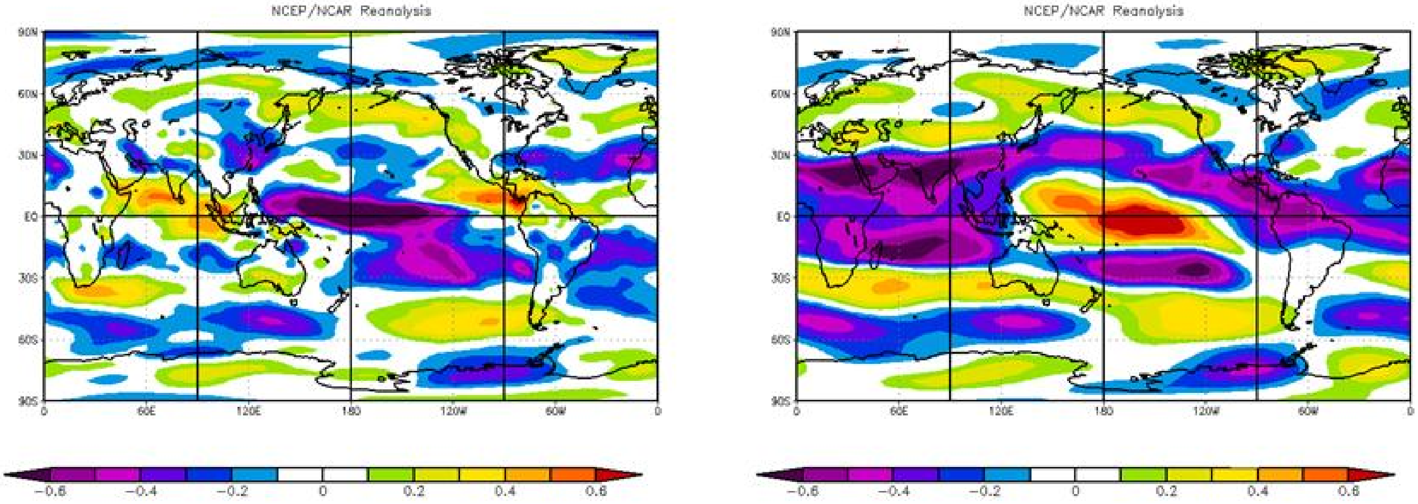


Figure 6: Linear correlations between June-July SLP in the tropical Atlantic (Predictor 2) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d). Sea level pressure values have been multiplied by -1 to allow for easy comparison with Figure 5.

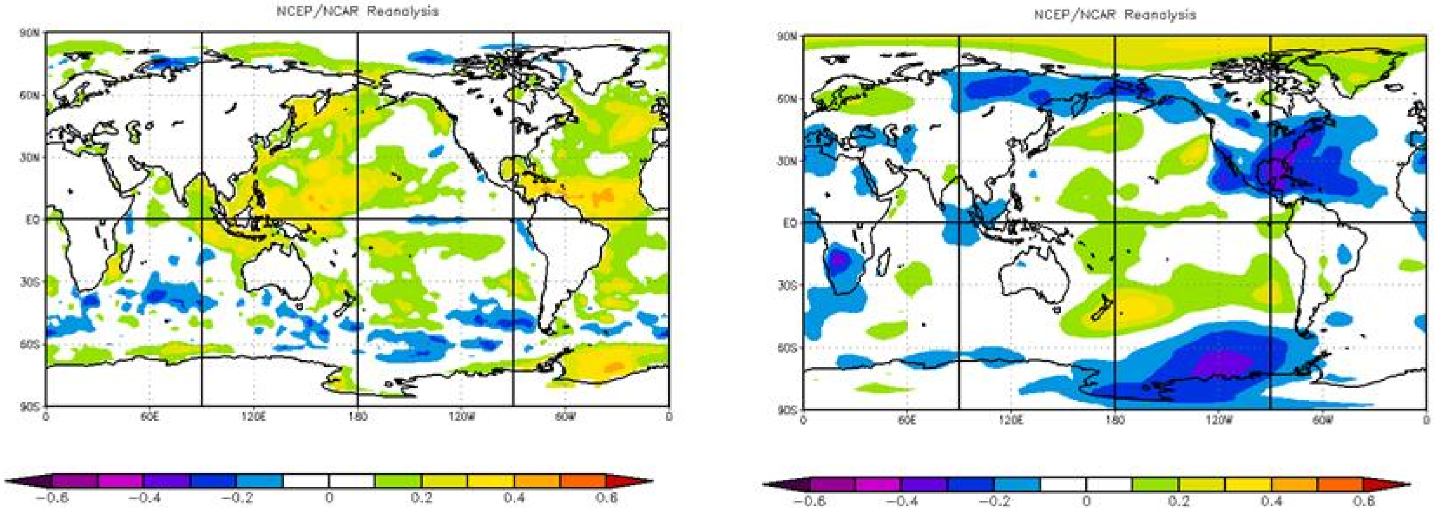

(a) SST

(b) SLP

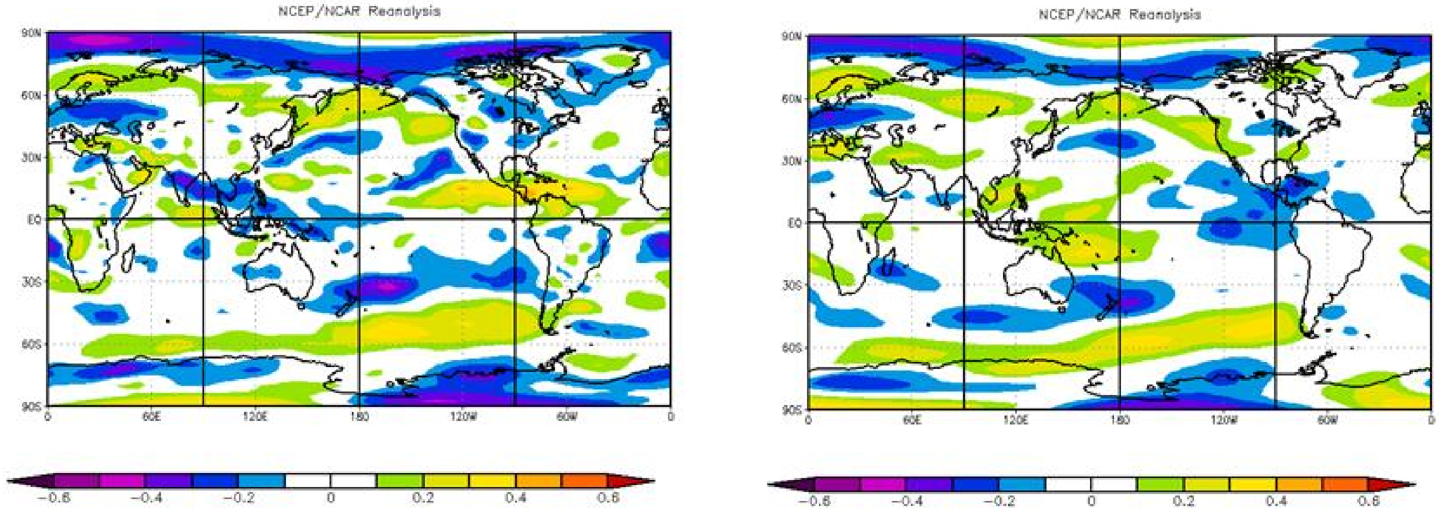

(c) 925 mb U

(d) 200 mb U

Figure 7: Linear correlations between June-July Nino 3 (Predictor 3) 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). Sea surface temperature values have been multiplied by -1 to allow for easy comparison with Figure 5.


(a) SST

(b) SLP


(c) 925 mb U

(d) 200 mb U

Figure 8: Linear correlations between June-July NSD in the tropics (Predictor 4) 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).

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 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 2010 hurricane forecast. Uncertainty ranges are given in one standard deviation (SD) increments.

Parameter	Hindcast Error (SD)	Post-31 July 2010 Forecast	Uncertainty Range – 1 SD (67% of Forecasts Likely in this Range)
Named Storms (NS)	2.3	16	14.7 – 19.3
Named Storm Days (NSD)	17.4	84.25	67.6 – 102.4
Hurricanes (H)	1.6	9	7.4 – 10.6
Hurricane Days (HD)	8.6	38.50	29.9 – 47.1
Major Hurricanes (MH)	0.9	5	4.1 – 5.9
Major Hurricane Days (MHD)	3.5	13	9.5 – 16.5
Accumulated Cyclone Energy (ACE)	36	178	142 – 214
Net Tropical Cyclone (NTC) Activity	34	186	154 - 222

4 Caribbean Forecast Methodology

We have developed a new forecast for the Caribbean that we are debuting this year. We find that predictors for the Caribbean are somewhat different than those used for the entire Atlantic basin. We intend to explore additional region-specific forecasts in the future, such as forecasts for the Gulf of Mexico or the higher latitude Atlantic.

We define the Caribbean to extend from 10-20°N, 60-88°W. This model attempts to predict seasonal levels of Accumulated Cyclone Energy (ACE) generated in the Caribbean. Through a combination of three predictors discussed in detail below, we can issue a forecast that shows significant levels of hindcast skill.

4.1 Caribbean Statistical Forecast Scheme

We have found that using three July predictors, we can obtain early August hindcasts that show considerable skill at predicting post-31 July ACE in the Caribbean over the sixty-year development period from 1949-2008.

This new scheme was created by evaluating three July predictors using least-squared regression. By definition, least-squared regression tends to be conservative, and therefore, predicting large outlier events can be quite challenging. In order to help adjust for this challenge, the hindcasts from the linear regression model were adjusted to the final hindcast in the following manner:

The standardized value of each hindcast was calculated. These hindcasts were then adjusted to the final hindcast by multiplying by the standard deviation of the observations. Since the standard deviation of the observations is considerably larger than the standard deviation of the hindcasts, this aids in the forecast of outlying events. Any hindcasts that resulted in a negative ACE prediction were assigned a final ACE value of 0.

Our statistical scheme shows significant hindcast skill, explaining 54% of the variance over the 1949-2008 period. Table 7 displays our early August hindcasts for 1949-2008 using the new statistical scheme, while Figure 9 displays observations versus post-31 July ACE hindcasts. The forecast for 2009 is also displayed. Our early August hindcasts have correctly predicted above- or below-average seasons in 50 out of 60 hindcast years (83%). These hindcasts have had a smaller error than climatology in 46 out of 60 years (77%). Our average hindcast error is 6.5 ACE units, compared with 11.6 ACE units for climatology. This scheme also shows considerable stability when broken in half, correlating at 0.71 from 1949-1978 and 0.78 from 1979-2008. This new scheme is also well-tuned to the multi-decadal active hurricane periods from 1950-1969 and 1995-2008 versus the inactive hurricane period from 1970-1994 (Table 8).

Figure 10 displays the locations of the early June predictors used in this scheme in map form. Table 9 lists the three predictors that are utilized for this year's June forecast.

Table 7: Observed versus hindcast post-31 July Caribbean ACE for 1949-2008. Average errors for hindcast ACE and climatological ACE predictions are given without respect to sign. Red bold-faced years in the "Hindcast ACE" column (2) are years that we did not go the right way, while red bold-faced years in the "Hindcast improvement over Climatology" column (5) are years that we did not beat climatology. The hindcast went the right way with regards to an above- or below-average season in 50 out of 60 years (83%), while hindcast improvement over climatology occurred in 46 out of 60 years (77%).

Year	(1) Observed ACE	(2) Hindcast ACE	(3) Observed minus Hindcast	(4) Observed minus Climatology	(5) Hindcast improvement over Climatology
1949	7	**24**	-17	-6	**-11**
1950	16	26	-9	3	**-6**
1951	24	21	3	10	7
1952	8	12	-4	-6	2
1953	4	9	-4	-9	4
1954	40	37	3	26	24
1955	48	39	9	35	26
1956	5	11	-6	-8	2
1957	0	9	-9	-13	5
1958	9	**23**	-14	-4	**-10**
1959	1	9	-8	-12	5
1960	8	**17**	-10	-6	**-4**
1961	24	26	-2	11	9
1962	0	6	-6	-13	7
1963	28	27	1	15	14
1964	21	21	0	7	7
1965	0	0	0	-13	13
1966	19	14	5	6	1
1967	27	21	6	14	8
1968	0	7	-7	-13	6
1969	12	12	0	-1	1
1970	2	**28**	-27	-12	**-15**
1971	19	**0**	19	6	**-13**
1972	0	0	0	-13	13
1973	0	**17**	-17	-13	**-4**
1974	18	21	-3	5	2
1975	4	**21**	-17	-9	**-8**
1976	1	0	1	-13	12
1977	1	3	-2	-13	11
1978	11	7	5	-2	**-3**
1979	26	18	8	12	5
1980	21	26	-5	8	2
1981	3	**20**	-17	-10	**-7**
1982	0	0	0	-13	13
1983	0	0	0	-13	13
1984	3	13	-10	-10	0
1985	1	5	-4	-12	8
1986	1	0	1	-12	11
1987	6	1	5	-7	2
1988	42	37	4	28	24
1989	16	**10**	6	3	**-3**
1990	6	**15**	-10	-8	**-2**
1991	0	0	0	-13	13
1992	0	0	0	-13	13
1993	4	4	0	-10	10
1994	3	0	3	-11	8
1995	23	26	-3	10	7
1996	16	16	-1	2	2
1997	3	0	3	-11	8
1998	44	43	1	31	30
1999	24	34	-10	11	1
2000	13	11	2	0	**-2**
2001	23	21	2	10	7
2002	6	0	6	-7	1
2003	3	8	-5	-11	6
2004	51	17	34	37	3
2005	30	28	2	16	15
2006	4	4	0	-9	9
2007	47	22	25	34	9
2008	21	34	-13	8	**-6**
Average	**13**	**15**	**6.5**	**11.6**	**5.1**
2009	4	10	-6	-9	3

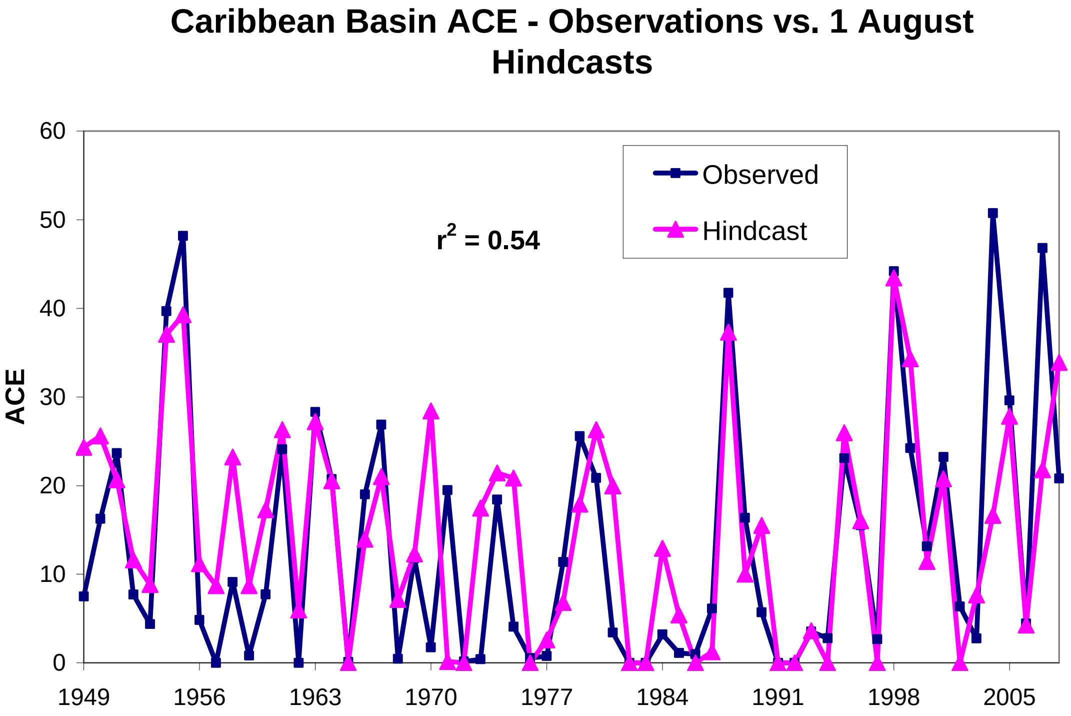


Figure 9: Observed versus hindcast values of post-31 July Caribbean Basin ACE for 1949-2008.

Table 8: Hindcast versus observed average ACE for active vs. inactive multi-decadal periods. Percentage differences from the climatological average (1949-2008) are in parentheses.

Years	*Average Observed ACE*	*Average Hindcast ACE*
1949-1969 (Active)	14 (108%)	18 (132%)
1970-1994 (Inactive)	8 (57%)	10 (75%)
1995-2008 (Active)	21 (156%)	18 (137%)

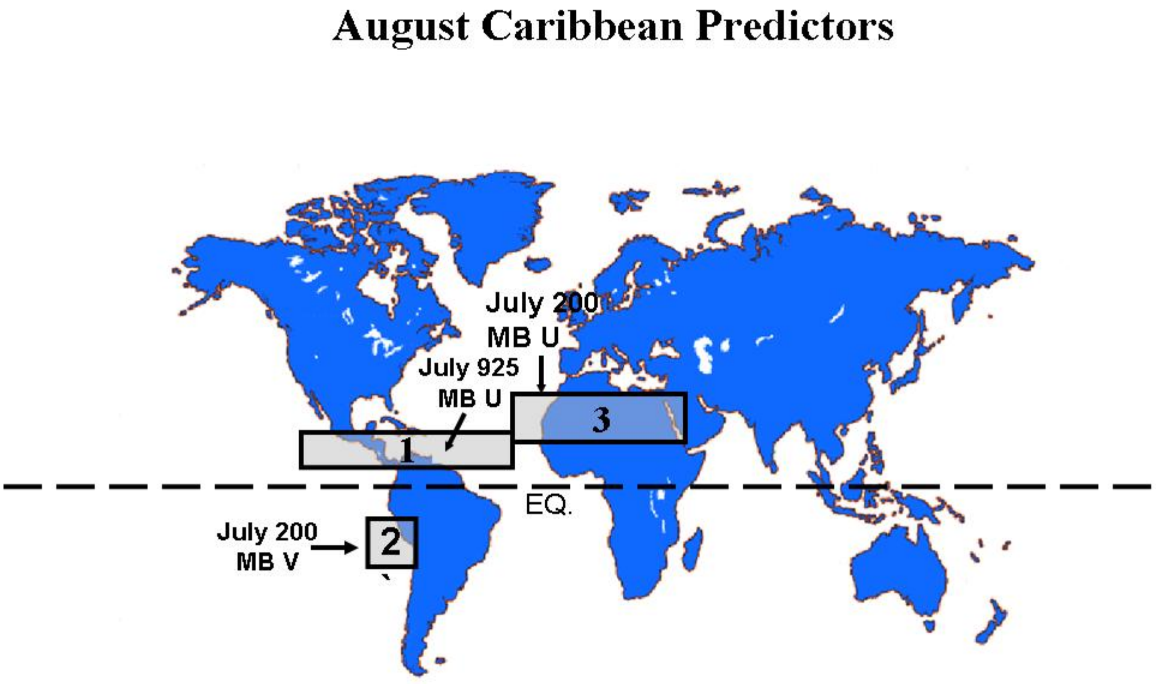


Figure 10: Location of July predictors for our post-31 July Caribbean statistical prediction for the 2010 hurricane season.

Table 9: Listing of 1 August 2010 Caribbean basin predictors using the August statistical model for the 2010 hurricane season. A plus (+) means that positive values of the parameter indicate increased hurricane activity during the post-31 July period.

Predictor	2010 Forecast Values
1) July 925 MB U (7.5-17.5°N, 20-120°W) (+)	+3.4 SD
2) July 200 MB V (10-25°S, 70-90°W) (-)	+1.2 SD
3) July 200 MB U (15-25°N, 20°W-50°E) (-)	-0.8 SD

The Caribbean model continues to call for a very active hurricane season in 2010. Our forecast model is calling for an ACE of 41, while the 1949-2008 average ACE for post-31 July ACE in the Caribbean is 13.

4.2 Physical Associations among Predictors Listed in Table 9

The locations and brief descriptions of the three July predictors for our August Caribbean statistical forecast are now discussed. It should be noted that all three forecast parameters correlate significantly with seasonal physical features that are known to be favorable for elevated levels of hurricane activity. Tables 10 and 11 display correlations between each predictor and August-October-averaged sea surface temperature, sea level pressure, 200 mb zonal wind and 925 mb zonal wind in the Main Development Region (MDR) and in the Caribbean, respectively. Since many storms that generate large values of ACE in the Caribbean form in the MDR, one would expect that these predictors would correlate with physical features in both regions. Correlations that are significant at the 95% level using a two-tailed Student's t-test are highlighted in bold-faced type. Although most of Predictor 2's correlations are weak, they are generally of the sign that would be expected to enhance tropical cyclone activity in the Atlantic. This predictor also correlates significantly at the 95% level over both the 1949-1978 and 1979-2008 time period, indicating stability of the predictor-tropical cyclone relationship throughout the developmental data period.

Table 10: Correlations between 1 August Caribbean predictors and August-October values of Main Development Region (10-20°N, 20-70°W) sea surface temperature, sea level pressure, 200 mb zonal wind and 925 mb zonal wind.

Predictor	SST	SLP	200 MB U	925 MB U
1) July 925 MB U (7.5-17.5°N, 20-120°W) (+)	**0.42**	**-0.58**	**-0.41**	**0.31**
2) July 200 MB V (10-25°S, 70-90°W) (-)	-0.03	0.19	0.22	-0.04
3) July 200 MB U (15-25°N, 20°W-50°E) (-)	0.01	**0.38**	**0.48**	-0.11

Table 11: Correlations between 1 August Caribbean predictors and August-October values of Caribbean (10-20°N, 60-88°W) sea surface temperature, sea level pressure, 200 mb zonal wind and 925 mb zonal wind.

Predictor	SST	SLP	200 MB U	925 MB U
1) July 925 MB U (7.5-17.5°N, 20-120°W) (+)	**0.37**	**-0.53**	**-0.54**	**0.67**
2) July 200 MB V (10-25°S, 70-90°W) (-)	-0.06	0.19	0.13	-0.15
3) July 200 MB U (15-25°N, 20°W-50°E) (-)	0.03	**0.32**	**0.56**	**-0.29**

As was done with our Atlantic basin forecast, for each of these predictors, we display a four-panel figure showing linear correlations between values of each predictor and August-October values of sea surface temperature, sea level pressure, 200 mb zonal wind, and 925 mb zonal wind, respectively. In general, higher values of SSTA, lower values of SLPA, anomalous westerlies at 925 mb and anomalous easterlies at 200 mb are associated with active Caribbean basin seasons.

Predictor 1. July 925 MB U in the Tropical Atlantic/Eastern Pacific (+)

(7.5-17.5°N, 20-120°W)

Anomalously weak trade winds during the month of July across the tropical Atlantic and eastern Pacific are strongly correlated with an active hurricane season in the Caribbean (Figure 11). These weaker trades are associated with higher-than-normal pressure in the tropical eastern Pacific and lower-than-normal pressure in the tropical Atlantic, characteristic of a La Niña event in the tropical Pacific. During the months of August-October, weaker trades reduce upwelling and mixing of the tropical Atlantic, driving warmer SSTs and lower sea level pressures. In addition, weaker trades in July tend to persist from August-October, which combined with anomalous easterly winds at upper levels (characteristic of a La Niña event) reduces levels of vertical shear both in the Caribbean and in the MDR.

Predictor 2. July 200 MB V off the west coast of South America (-)

(10-25°S, 70-90°W)

Upper-level northerly winds off of the west coast of South America are associated with an anomalous ridge over South America and an anomalous trough in the tropical eastern and central Pacific. This anomalous upper-level trough is typically associated with cold waters (La Niña) in the eastern and central Pacific. Blake (2004) has shown that an upper-level ridge over South America is favorable for an active August due to an associated reduction in upper-level westerly winds over the tropical Atlantic. Negative values of this predictor tend to be associated with lower-than-normal sea level pressures and reduced vertical shear over both the Caribbean and the MDR (Figure 12).

Predictor 3. July 200 MB U over North Africa (-)

(15-25°N, 20°W-50°E)

Anomalous upper-level easterly winds over North Africa in July are typically associated with an active African monsoon and La Niña conditions (Figure 13). These upper-level easterly winds in July tend to persist through the August-October time period and are very strongly correlated with anomalous upper-level easterly winds throughout the MDR and the Caribbean during the August-October period. Lower-sea-level pressures in the tropical Atlantic are also associated with easterly anomalies over North Africa. Reduced vertical shear provides for a more favorable dynamic environment for storm formation and intensification, while lower-than-normal sea level pressures imply a more favorable thermodynamic environment.

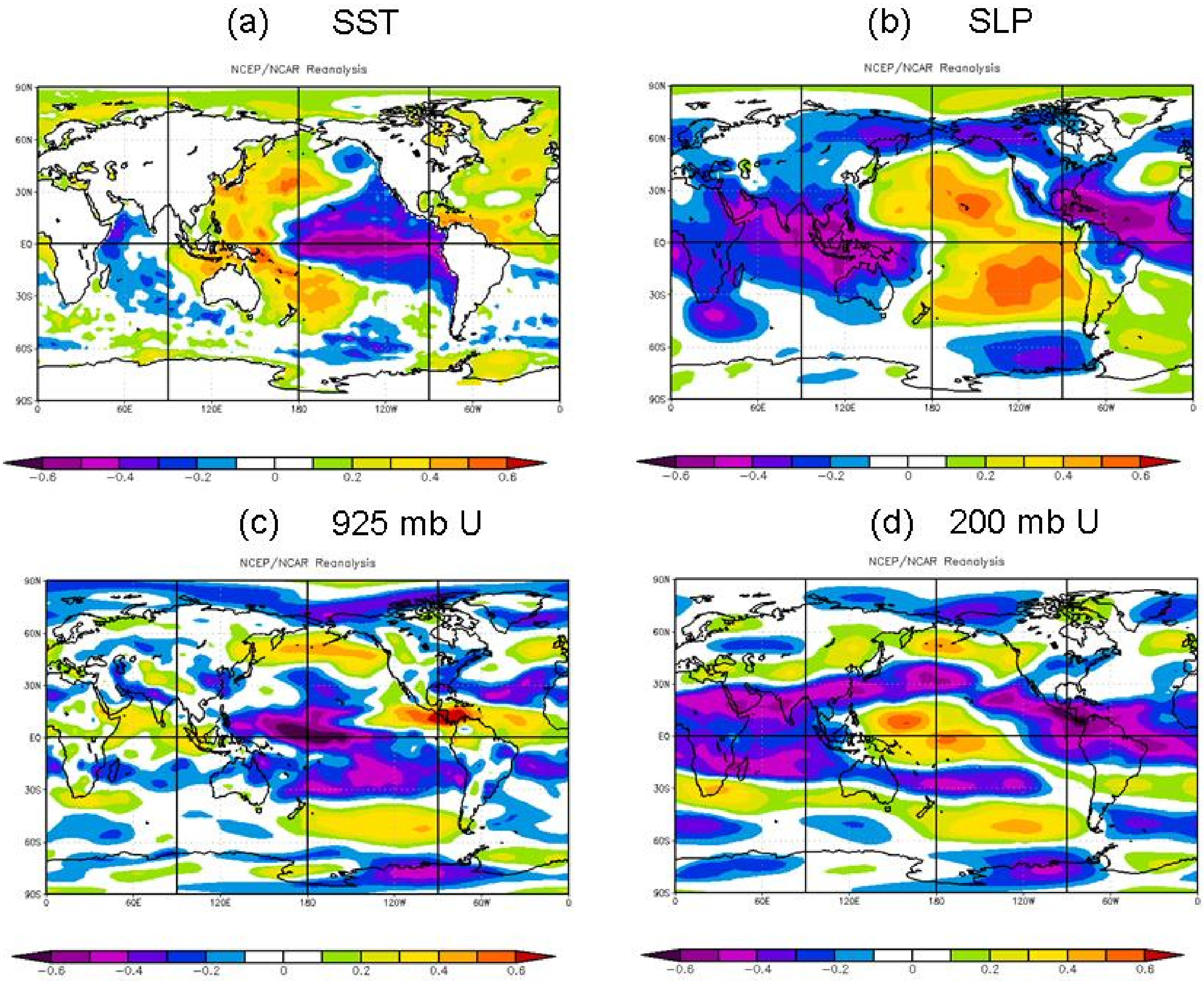
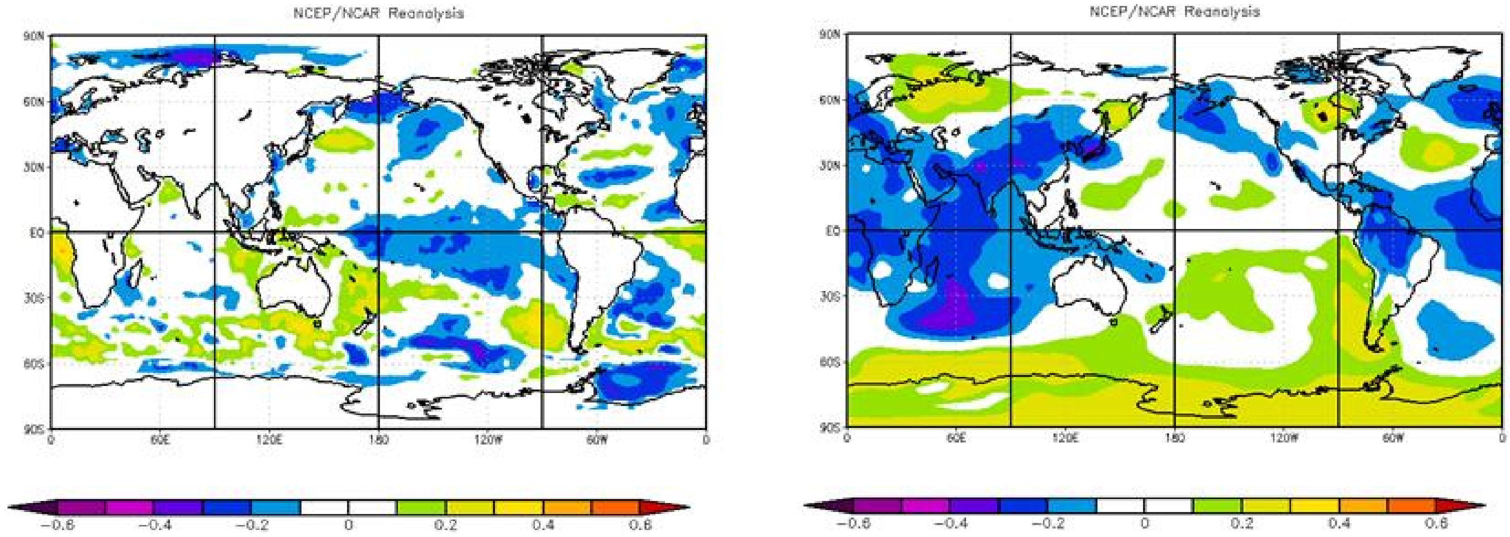


Figure 11: Linear correlations between July 925 mb zonal wind in the tropical Atlantic/eastern Pacific (Predictor 1) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d). All four of these parameter deviations are known to be favorable for enhanced hurricane activity.



(a) SST

(b) SLP

(c) 925 mb U

(d) 200 mb U

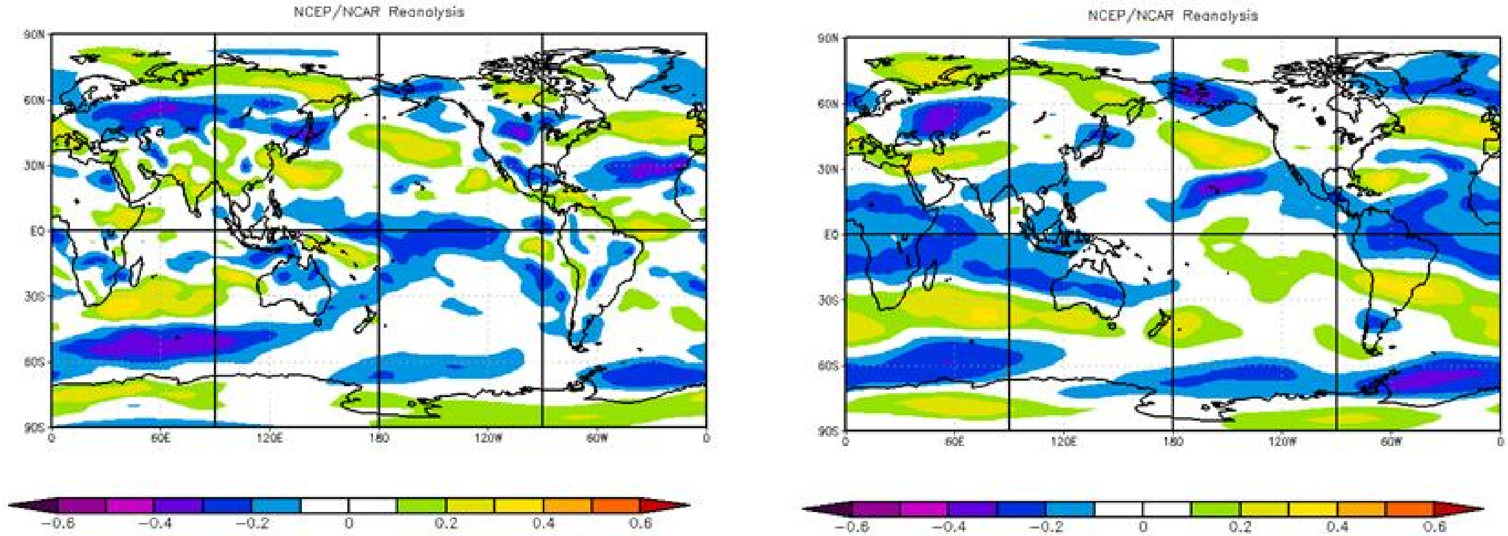
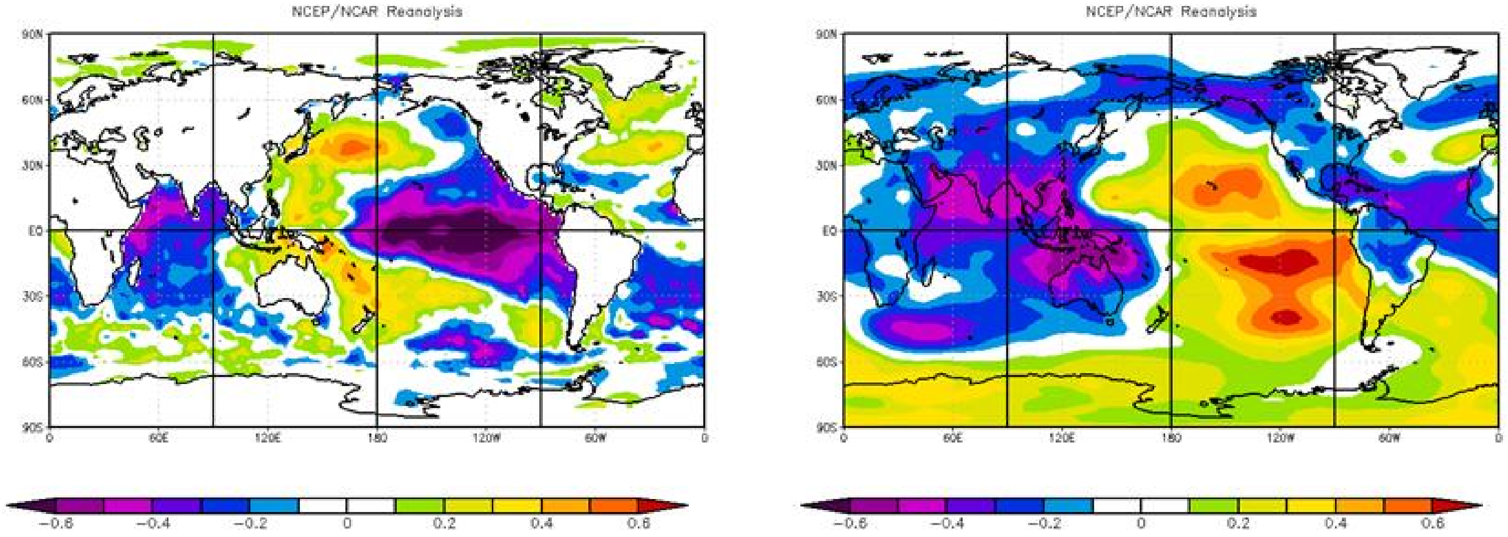


Figure 12: Linear correlations between July 200 mb meridional wind near the west coast of South America (Predictor 2) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d). All four of these parameter deviations are known to be favorable for enhanced hurricane activity. Zonal wind values have been multiplied by -1 to allow for easy comparison with Figure 11.

(a) SST (b) SLP



(c) 925 mb U (d) 200 mb U

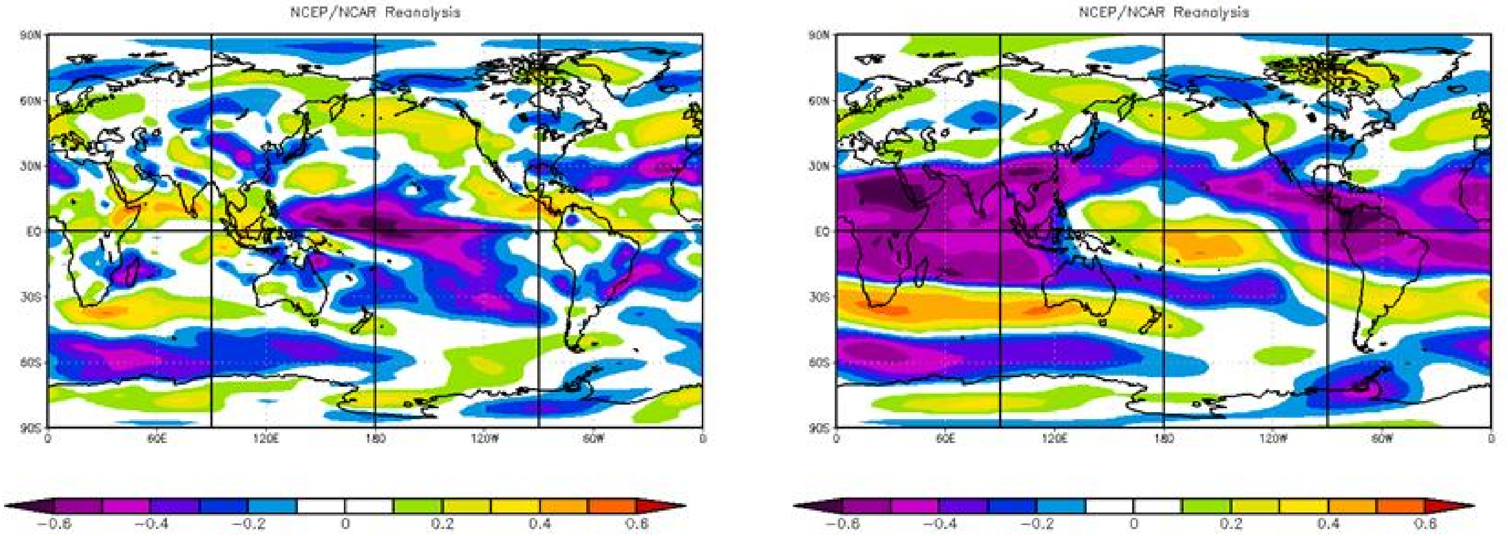


Figure 13: Linear correlations between July 200 mb zonal wind over North Africa (Predictor 3) and August-October sea surface temperature (panel a), August-October sea level pressure (panel b), August-October 925 mb zonal wind (panel c) and August-October 200 mb zonal wind (panel d). All four of these parameter deviations are known to be favorable for enhanced hurricane activity. Zonal wind values have been multiplied by -1 to allow for easy comparison with Figure 11.

5 Analog-Based Predictors for 2010 Hurricane Activity

Certain years in the historical record have global oceanic and atmospheric trends which are substantially similar to 2010. These years also provide useful clues as to likely trends in activity that the 2010 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 2010 conditions. Table 12 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 the closest optimal combination of weak to moderate La Niña conditions and very warm tropical Atlantic and far North Atlantic sea surface temperatures.

There were four hurricane seasons with characteristics most similar to what we observed in June-July 2010. The best analog years that we could find for the 2010 hurricane season were 1952, 1958, 1998 and 2005. We anticipate that 2010 seasonal hurricane activity will have activity that is in line with the average of these four analog years. We believe that 2010 will have well above-average activity in the Atlantic basin.

Table 12: Best analog years for 2010 with the associated hurricane activity listed for each year.

Year	NS	NSD	H	HD	MH	MHD	ACE	NTC
1952	7	39.75	6	22.75	3	7	87	103
1958	10	55.50	7	30.25	5	9.50	121	144
1998	14	88.00	10	48.50	3	9.50	182	169
2005	28	131.50	15	49.75	7	17.75	250	279
Mean	17.3	91.7	10.7	42.8	5.0	12.3	184	198
2010 Forecast	18	90	10	40	5	13	185	195

6 ENSO

Conditions in the tropical Pacific have transitioned to La Niña over the past couple of months. Sea surface temperature anomalies across the central and eastern tropical Pacific have dropped below the -0.5°C anomaly threshold which is typically associated with La Niña events. Table 13 displays July and May SST anomalies for several Nino regions. Note that the entire central and eastern tropical Pacific has cooled significantly during the past two months.

Table 13: May and July 2010 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 Cooling (°C)
Nino 1+2	-0.1	-1.7	-1.6
Nino 3	-0.1	-1.1	-1.0
Nino 3.4	-0.1	-1.1	-1.0
Nino 4	0.4	-0.6	-1.0

The transition from El Niño to La Niña has been quite rapid this year. Most forecast models are calling for a continued cooling of tropical Pacific sea surface temperatures (Figure 14). At this point, we expect that a moderate La Niña will be in place over the August-October period (defined as an August-October-averaged Nino 3.4 index between -0.5 and -1.0°C).

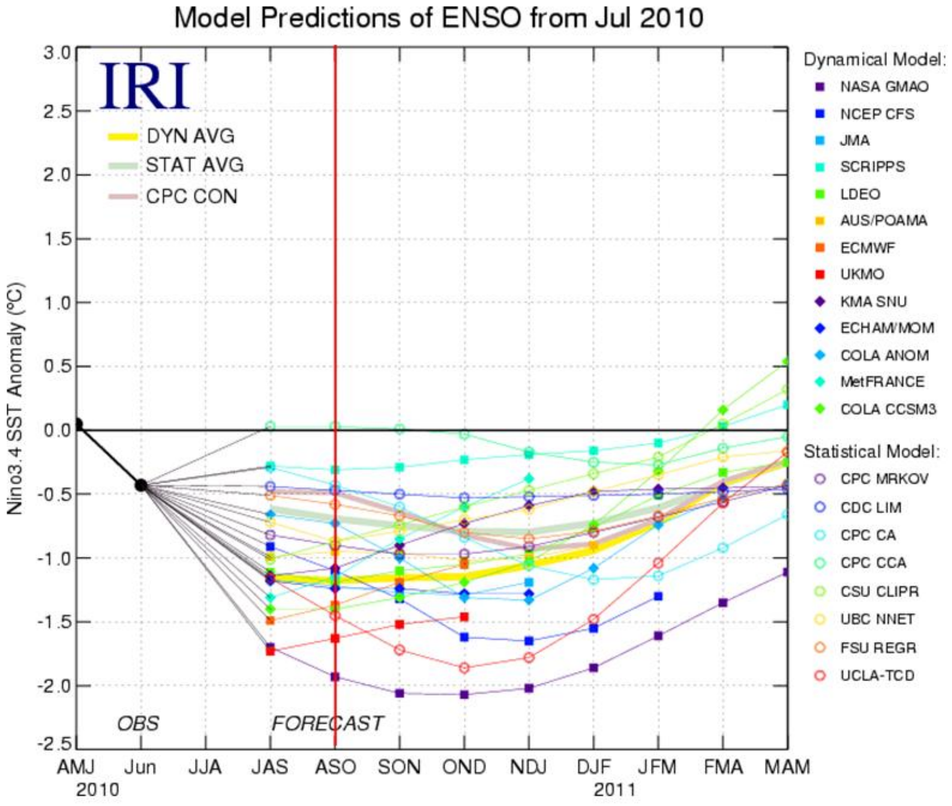


Figure 14: ENSO forecasts from various statistical and dynamical models. Figure courtesy of the International Research Institute (IRI).

Typically, years that have La Niña conditions are much more active for Atlantic basin hurricanes, and also for United States landfalls. Table 14 displays the average number of hurricane and major hurricane impacts along the United States coastline in El Niño (ASO-averaged Nino 3.4 SST >= 0.5°C) years, neutral years (ASO-averaged Nino 3.4 SST between -0.5°C and 0.5°C), and La Niña years (ASO-averaged Nino 3.4 SST <= -0.5°C). The probability of the United States being impacted by a major hurricane increases from 27% to 66% from El Niño to La Niña, based on data from 1900-2009.

Table 14: Average per-year number of hurricane and major hurricane impacts along the United States coastline for El Niño years, neutral years and La Niña years based on data from 1900-2009. These average per-year impacts are converted into the annual probability of one or more hurricane and major hurricane impacts using the Poisson distribution.

	Hurricane Impacts (per-year)	Major Hurricane Impacts (per-year)	Hurricane Impact Probability	Major Hurricane Impact Probability
El Nino	1.0	0.3	65%	27%
Neutral	1.6	0.6	79%	45%
La Nina	2.7	1.1	93%	66%

7 Current Atlantic Basin Conditions

Conditions in the Atlantic remain very favorable for an active Atlantic hurricane season. SST anomalies across the MDR and the Caribbean are currently running at near-record levels (Figure 15). These warm anomalies developed during the late winter and early spring months due to a very weak Azores High and a consequent reduction in the strength of the trade winds. July sea level pressure anomalies have been well below average throughout the tropical Atlantic (Figure 16), feeding back into continued reduced trade wind strength. This positive feedback has helped to keep tropical Atlantic SST anomalies at very warm levels. We believe that the very warm tropical Atlantic combined with a likely moderate La Niña event will lead to a very active hurricane season.

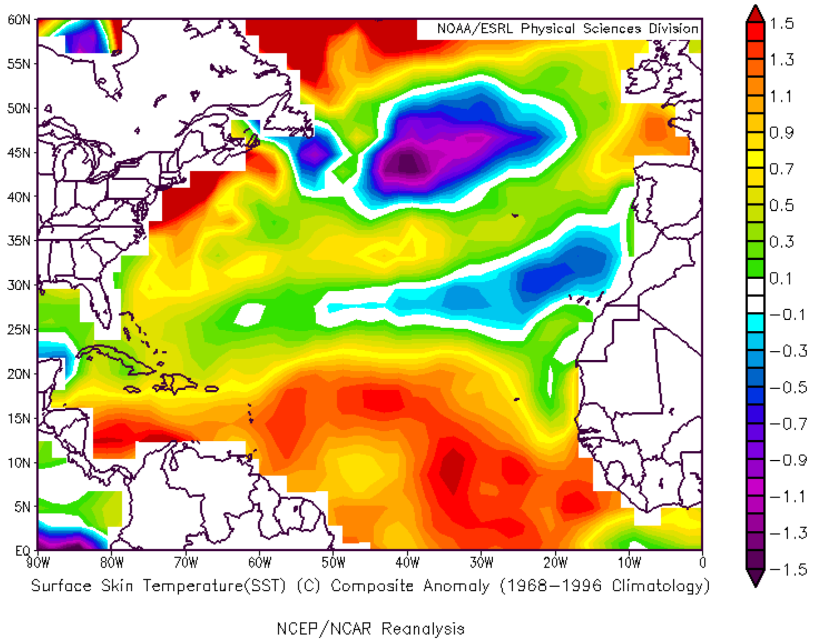


Figure 15: July 2010 SST anomaly. Note the large positive anomalies throughout the tropical Atlantic and Caribbean.

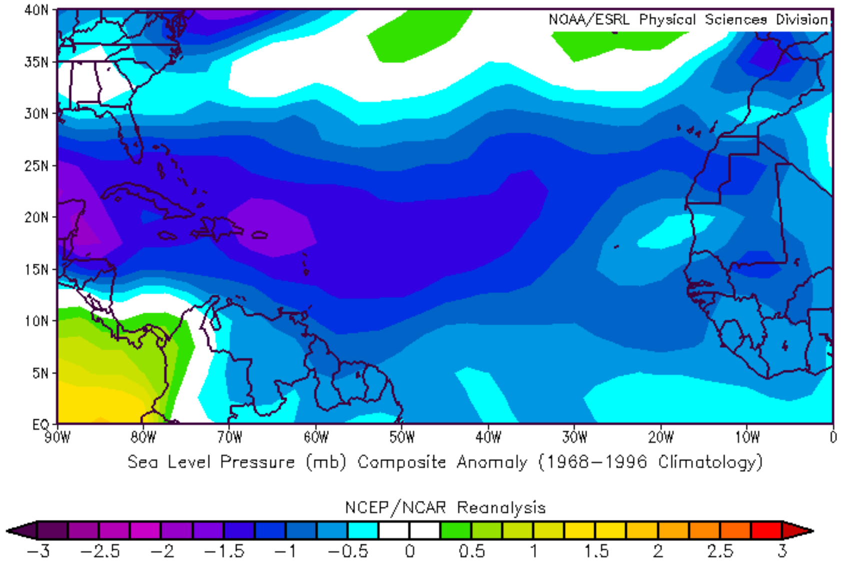


Figure 16: July 2010 Atlantic SLP anomaly. Note the large negative anomalies throughout the tropical Atlantic and Caribbean.

8 Adjusted 2010 Forecast

Table 15 shows our final adjusted early August forecast for the 2010 season which is a combination of our statistical scheme (with June-July activity added in), our analog forecast and qualitative adjustments for other factors not explicitly contained in either of these schemes. Our statistical forecast calls for an active season, while our analog forecast indicates activity at very high levels. We foresee a very active Atlantic basin hurricane season due to the development of La Niña and very favorable SSTA and SLPA conditions in the tropical Atlantic.

Table 15: Summary of our early August full season statistical forecast, our analog forecast and our adjusted final forecast for the 2010 hurricane season.

Forecast Parameter and 1950-2000 Climatology (in parentheses)	Statistical Scheme	Analog Scheme	Adjusted Final Forecast
Named Storms (9.6)	13.1	17.3	18
Named Storm Days (49.1)	63.5	91.7	90
Hurricanes (5.9)	7.7	10.7	10
Hurricane Days (24.5)	30.0	42.8	40
Major Hurricanes (2.3)	3.2	5.0	5
Major Hurricane Days (5.0)	7.8	12.3	13
Accumulated Cyclone Energy Index (96.1)	124	184	185
Net Tropical Cyclone Activity (100%)	135	198	195

9 Landfall Probabilities for 2010

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 accurately forecast months in advance, the total seasonal probability of landfall can be forecast with statistical skill. With the observation that, statistically, 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 16). 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 16: 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 17 lists post-31 July strike probabilities for the 2010 hurricane season for different TC categories for the entire U.S. coastline, the Gulf Coast and the East Coast including the Florida peninsula. In our early June forecast of 2009, we initiated landfall probabilities for various islands and landmasses in the Caribbean and in Central America. Note that Atlantic basin NTC activity in 2010 is expected to be above its long-term average of 100, and therefore, landfall probabilities are above their long-term average.

Please 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. The probability of each U.S. coastal state being impacted by hurricanes and major hurricanes is also included. In addition, we now include probabilities of named storms, hurricanes and major hurricanes tracking within 50 and 100 miles of various islands and landmasses in the Caribbean and Central America.

Table 17: Post-31 July 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 2010 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)	95% (79%)	88% (68%)	75% (52%)	97% (84%)	99% (97%)
Gulf Coast (Regions 1-4)	81% (59%)	64% (42%)	49% (30%)	82% (60%)	97% (83%)
Florida plus East Coast (Regions 5-11)	73% (50%)	66% (44%)	50% (31%)	83% (61%)	96% (81%)
Caribbean (10-20°N, 60-88°W)	96% (82%)	79% (57%)	64% (42%)	93% (75%)	99% (96%)

We are now also calculating state hurricane impact probabilities utilizing the Atlantic basin hurricane impact dataset created by the National Hurricane Center available here: http://www.aoml.noaa.gov/hrd/hurdat/ushurrlist18512008_jun09.txt. This dataset calculates which states were impacted by all hurricanes making U.S. landfall. We have calculated probabilities of each state being impacted by a hurricane and major hurricane using data from 1856-2008. Several states can be impacted by the same tropical cyclone, for example, Hurricane Katrina impacted Louisiana and Mississippi as a Category 3 hurricane while impacting Florida and Alabama as a Category 1 hurricane. Current-year and climatological probabilities of hurricane impact by state are now available on our Landfalling Probability Webpage (http://www.e-transit.org/hurricane). Table 18 displays climatological and current-year probabilities for each state being impacted by a hurricane and major hurricane.

Table 18: Current-year and climatological (in parentheses) probabilities for each coastal state being impacted by a hurricane and major hurricane based on data from 1856-2008. States are sorted by the probability of being impacted by a hurricane.

Coastal State	Hurricane Probability	Major Hurricane Probability
Florida	74% (51%)	36% (21%)
Texas	53% (33%)	21% (12%)
Louisiana	49% (30%)	21% (12%)
North Carolina	47% (28%)	14% (8%)
South Carolina	30% (17%)	7% (4%)
Alabama	27% (16%)	5% (3%)
Northeast U.S. (NY, CT, RI, MA, NH, ME)	20% (11%)	8% (4%)
Georgia	20% (11%)	2% (1%)
Mississippi	19% (11%)	8% (4%)
New York	14% (8%)	6% (3%)
Mid-Atlantic (VA, MD, DE, NJ)	14% (8%)	1% (1%)
Connecticut	13% (7%)	4% (2%)
Massachusetts	13% (7%)	4% (2%)
Virginia	12% (6%)	1% (1%)
Rhode Island	10% (6%)	5% (3%)
Maine	7% (4%)	<1% (<1%)
Delaware	2% (1%)	<1% (<1%)
Maryland	2% (1%)	<1% (<1%)
New Hampshire	2% (1%)	<1% (<1%)
New Jersey	2% (1%)	<1% (<1%)

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. In addition, three category 2 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 have been given much media attention; however, we believe that they are not valid, given current observational data.

There has, however, been a large increase in Atlantic basin major hurricane activity since 1995 in comparison with the prior 15-year period of 1980-1994 (Figure 17) as well as the prior quarter-century period of 1970-1994. It has been tempting for many who do not have a strong background in hurricane knowledge 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 15-year active major hurricane period of 1995-2009 has, however, not been more active than the earlier 15-year period of 1950-1964 when the Atlantic Ocean circulation conditions were similar to what has been observed in the last 15 years. These conditions occurred even though atmospheric CO_2 amounts were lower during the earlier period.

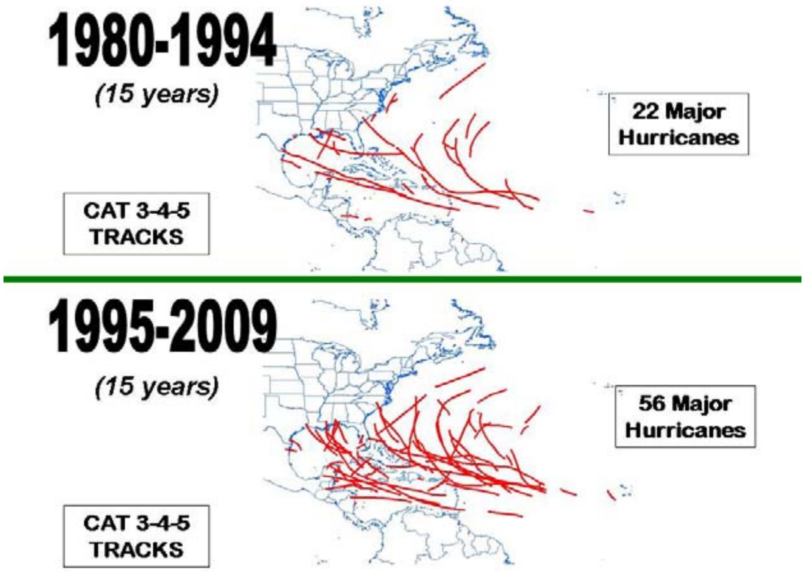


Figure 17: The tracks of major (Category 3-4-5) hurricanes during the 15-year period of 1995-2009 when the Atlantic thermohaline circulation (THC) was strong versus the prior 15-year period of 1980-1994 when the THC was weak. Note that there were more than 2.5 times as many major hurricanes when the THC was strong as when it was weak.

Table 19 shows how large Atlantic basin hurricane variations are between strong and weak THC periods. Note especially how large the ratio is for major hurricane days (3.8) during strong vs. weak THC periods. Normalized U.S. hurricane damage studies by Pielke and Landsea (1998) show that landfalling major hurricanes account on average for about 80-85 percent of all hurricane-related destruction even though these major hurricanes make up only 20-25 percent of named storms.

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 1979. Global Accumulated Cyclone Energy (ACE) shows significant year-to-year and decadal variability over the past thirty years but no increasing trend (Figure 18). Similarly, Klotzbach (2006) found no significant change in global TC activity during the period from 1986-2005.

Table 19: Comparison of Atlantic annual basin hurricane activity in two 15-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
1950-1964 (15 years)	Strong	27.93	320	9.9	53.6	6.5	30.5	3.8	9.8	122	134
1970-1994 (25 years)	Weak	27.60	345	9.3	41.9	5.0	16.0	1.5	2.5	68	75
1995-2009 (15 years)	Strong	27.97	372	14.5	73.9	7.7	31.9	3.7	9.2	140	151
Annual Ratio Strong/Weak THC		Δ 0.35°C	~ 0	1.3	1.5	1.4	1.9	2.5	3.8	1.9	1.9

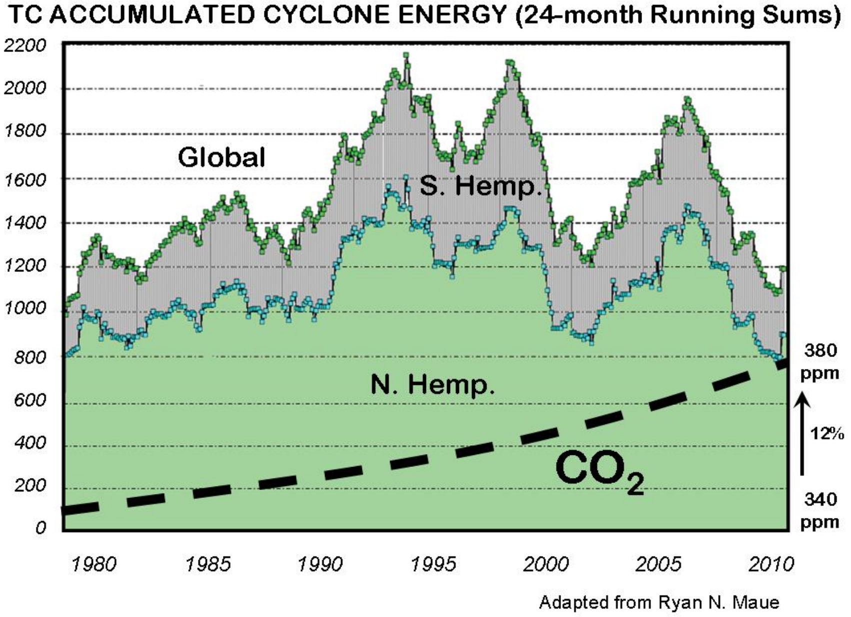


Figure 18: Northern Hemisphere, Southern Hemisphere, and global ACE over the period from 1979-2009. Figure has been adapted from Ryan Maue, Center for Ocean-Atmospheric Prediction Studies, Florida State University.

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 19). 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 sea surface temperature anomaly (SSTA) in the North Atlantic (Figure 20) 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 especially at water temperatures near freezing. There is a strong association between North Atlantic SSTA and North Atlantic salinity (Figure 21). 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 Grossman and Klotzbach (2009) for more discussion.

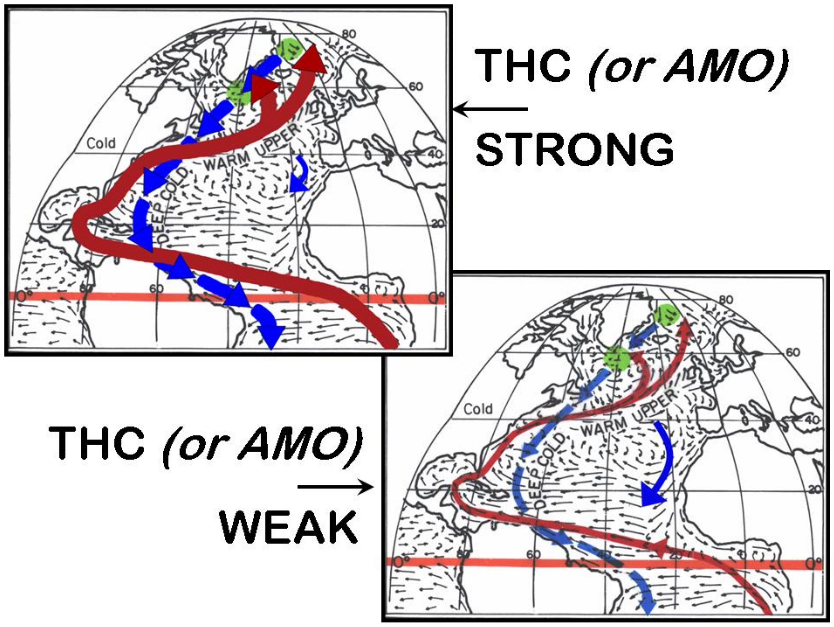


Figure 19: Illustration of strong (top) and weak (bottom) phases of the THC or AMO.

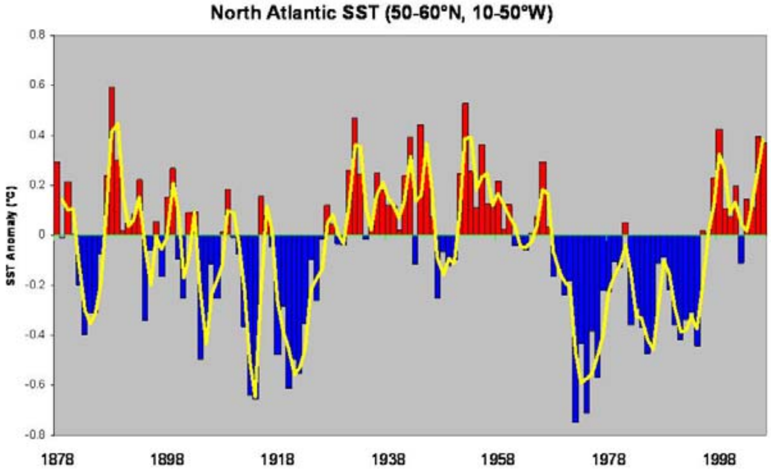


Figure 20: Long-period portrayal (1878-2006) of North Atlantic sea surface temperature anomalies (SSTA). The red (warm) periods are when the THC (or AMO) is stronger than average and the blue periods are when the THC (or AMO) is weaker than average.

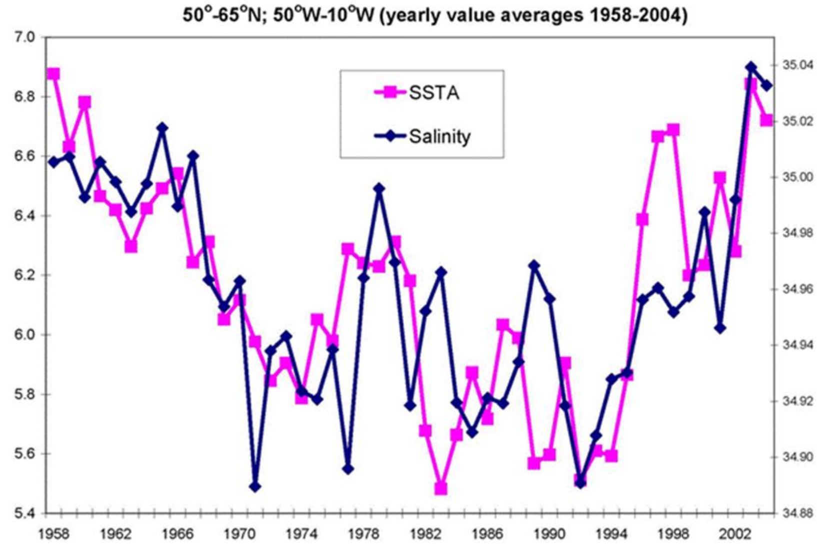


Figure 21: Illustration of the strong association of yearly average North Atlantic SSTA and North Atlantic salinity content between 1958 and 2004.

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 a rapid 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 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 necessarily 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 slightly lower.

CO_2 Influence on Hurricane Activity. We have been performing research with the International Satellite Cloud Climatology Project (ISCCP) and the NOAA National Centers for Environmental Prediction (NCEP) Reanalysis data sets. We have used this data to make an annual average of the global tropical (30°N-30°S; 0-360°) energy budget (Figure 22) for the years from 1984-2004. Note that the various surface and top of the atmosphere energy fluxes are very large. For the tropical surface, for instance, there are 637 Wm^{-2} units of downward incoming solar and infrared (IR) energy. This downward energy flux is largely balanced by an upward surface energy flux of 615 Wm^{-2} which is due to upward fluxes from IR radiation, evaporated liquid water, and sensible heat. Similar large energy fluxes are present at the top of the atmosphere and within the troposphere.

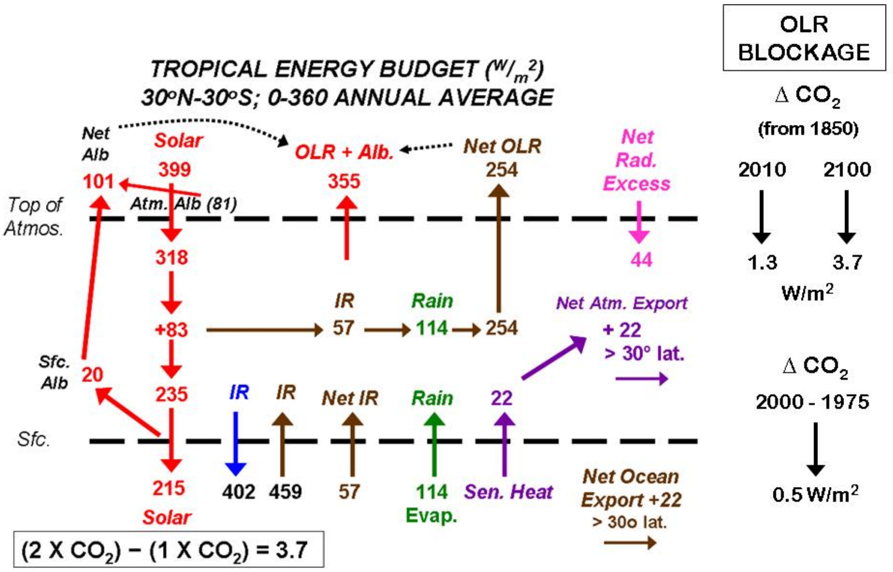


Figure 22: Vertical cross-section of the annual tropical energy budget as determined from a combination of ISCCP and NCEP Reanalysis data over the period from 1984-2004. Abbreviations are **IR** for longwave infrared radiation, **Alb** for albedo and **OLR** for outgoing longwave radiation. The tropics receive an excess of about 44 Wm^{-2} radiation energy which is convected and exported as sensible heat to latitudes poleward of 30°. Estimates are about half (22 Wm^{-2}) of this excess is transported by the atmosphere and the other half is transported by the oceans. Note, on the right, how small an OLR blockage has occurred up to now due to CO_2 increases (~ 1.3 Wm^{-2}) and a continued small blockage of 3.7 Wm^{-2} that will occur from a doubling of CO_2 by the end of this century.

It has been estimated that a doubling of CO_2 (from the pre-industrial period) without any feedback influences would result in a blockage of OLR to space of about 3.7 Wm^{-2}. The currently-measured value of CO_2 in the atmosphere is 380 parts per million by volume (ppmv). If we take the background pre-industrial value of CO_2 to be 280 ppmv, then by theory we should currently be having (from CO_2 increases alone) about (100/280)*3.7 = 1.3 Wm^{-2} less OLR energy flux to space than was occurring in the mid-19th century.

This reduced OLR of 1.3 Wm^{-2} is very small in comparison with most of the other tropical energy budget exchanges. Slight changes in any of these other larger tropical energy budget components could easily negate or reverse this small CO_2-induced OLR blockage. For instance, an upper tropospheric warming of about 1°C with no change in moisture would enhance OLR sufficiently that it would balance the reduced OLR influence from a doubling of CO_2. Similarly, if there were a reduction of upper level water vapor such that the long wave radiation emission level to space were lowered by about 7 mb (~ 140 m), there would be an enhancement of OLR (with no change of temperature) sufficient to balance the suppression of OLR from a doubling of CO_2. The 1.3 Wm^{-2} reduction in OLR we have experienced since the mid-19th century (about one-third of the way to a doubling of CO_2) is very small compared with the overall 399 Wm^{-2} of solar energy impinging on the top of the tropical atmosphere and the mostly compensating 356 Wm^{-2} of OLR and albedo energy going back to space. This 1.3 Wm^{-2} energy gain is much too small to ever allow a determination of its possible influence on TC activity. Any such potential CO_2 influence on TC activity is deeply buried as turbulence within the tropical atmospheres' many other energy components. It is possible that future higher atmospheric CO_2 levels may cause a small influence on global TC activity. But any such potential influence would likely never be able to be detected, given that our current measurement capabilities only allow us to assess TC intensity to within about 5 mph.

C. DISCUSSION

In a global warming or global cooling world, the atmosphere's upper air temperatures will warm or cool in unison with the SSTs. Vertical lapse rates will not be significantly altered. 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 23). Atlantic SSTs and hurricane activity do not follow global mean temperature trends.

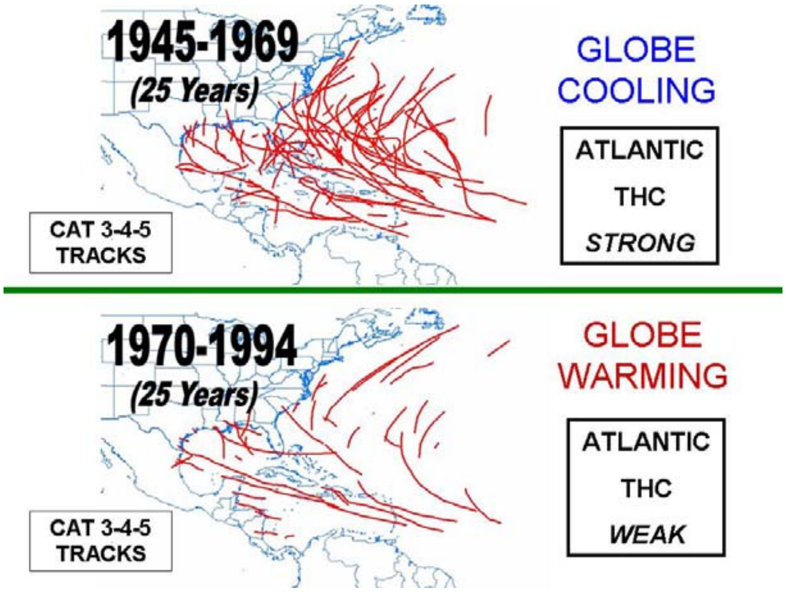


Figure 23: Tracks of major (Category 3-4-5) hurricanes during the 25-year period of 1945-1969 when the globe was undergoing a weak cooling versus the 25-year period of 1970-1994 when the globe was undergoing a modest warming. CO_2 amounts in the later period were approximately 18 percent higher than in the earlier period. Major Atlantic hurricane activity was only about one-third 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 20). Although global mean ocean and Atlantic SSTs have increased by about 0.4°C between these two 55-year periods (1900-1954 compared with 1955-2009), 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 44-year period of 1922-1965 (24 landfall events) and the 44-year period of 1966-2009 (7 landfall events) was especially large (Figure 24). For the entire United States coastline, 38 major hurricanes made landfall during the earlier 44-year period (1922-1965) compared with only 26 major hurricanes for the latter 44-year period (1966-2009). 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 20: U.S. landfalling tropical cyclones by intensity during two 55-year periods.

YEARS	***Named Storms***	***Hurricanes***	***Major Hurricanes (Cat 3-4-5)***	***Global Temperature Increase***
1900-1954 (55 years)	208	113	44	+0.4°C
1955-2009 (55 years)	184	90	36	

We should not read too much into the three very active hurricane seasons of 2004, 2005, and 2008. 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.

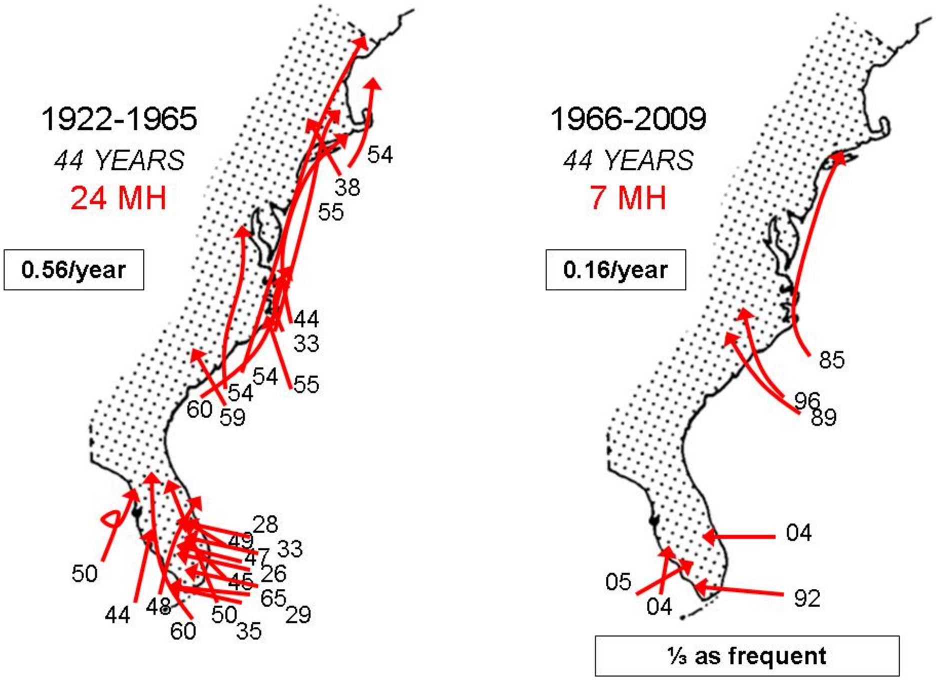


Figure 24: Contrast of tracks of East Coast and Florida Peninsula major landfalling hurricanes during the 44-year period of 1922-1965 versus the most recent 44-year period of 1966-2009.

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 21 named storms in a year when there was no satellite or aircraft data. Records of 1933 show all 21 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) – the same number as was observed to occur 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 thousand of years. These changes are natural and have nothing to do with human activity.

11 Forthcoming Updated Forecasts of 2010 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 4). Additional two-week forecasts will be issued every other Wednesday (e.g., August 18, September 1, etc.) The full schedule of two-week forecasts is available here: http://tropical.atmos.colostate.edu/Includes/Documents/Two_Week_Forecasts.html. A verification and discussion of all 2010 forecasts will be issued in late November 2010. Our first seasonal hurricane forecast for the 2011 hurricane season will be issued in early December 2010. 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, Todd Kimberlain, Paul Roundy and

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14 Verification of Previous Forecasts

Table 21: Summary verification of the authors' six previous years of seasonal forecasts for Atlantic TC activity between 2004-2009.

		Update	Update	Update	
2004	5 Dec. 2003	2 April	28 May	6 August	Obs.
Named Storms	13	14	14	13	15
Named Storm Days	55	60	60	55	93
Hurricanes	7	8	8	7	9
Hurricane Days	30	35	35	30	45.50
Major Hurricanes	3	3	3	3	6
Major Hurricane Days	6	8	8	6	22.25
Net Tropical Cyclone Activity	125	145	145	125	232

		Update	Update	Update	
2005	3 Dec. 2004	1 April	31 May	5 August	Obs.
Named Storms	11	13	15	20	28
Named Storm Days	55	65	75	95	131.50
Hurricanes	6	7	8	10	15
Hurricane Days	25	35	45	55	49.75
Major Hurricanes	3	3	4	6	7
Major Hurricane Days	6	7	11	18	17.75
Net Tropical Cyclone Activity	115	135	170	235	279

		Update	Update	Update	
2006	6 Dec. 2005	4 April	31 May	3 August	Obs.
Named Storms	17	17	17	15	10
Named Storm Days	85	85	85	75	52.75
Hurricanes	9	9	9	7	5
Hurricane Days	45	45	45	35	21.25
Major Hurricanes	5	5	5	3	2
Major Hurricane Days	13	13	13	8	2
Net Tropical Cyclone Activity	195	195	195	140	85

		Update	Update	Update	
2007	8 Dec. 2006	3 April	31 May	3 August	Obs.
Named Storms	14	17	17	15	15
Named Storm Days	70	85	85	75	37.75
Hurricanes	7	9	9	8	6
Hurricane Days	35	40	40	35	12.25
Major Hurricanes	3	5	5	4	2
Major Hurricane Days	8	11	11	10	6
Net Tropical Cyclone Activity	140	185	185	160	99

		Update	Update	Update	
2008	7 Dec. 2007	9 April	3 June	5 August	Obs.
Named Storms	13	15	15	17	16
Named Storm Days	60	80	80	90	88.25
Hurricanes	7	8	8	9	8
Hurricane Days	30	40	40	45	30.50
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

		Update	Update	Update	
2009	10 Dec. 2008	9 April	2 June	4 August	Obs.
Named Storms	14	12	11	10	9
Named Storm Days	70	55	50	45	30
Hurricanes	7	6	5	4	3
Hurricane Days	30	25	20	18	12
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