June 2010

2009 Atlantic Hurricane Season Review and 2010 Season Outlook

RMS® Catastrophe Response

CONTENTS

EXECUTIVE SUMMARY

The 2009 Atlantic Hurricane Season

The 2009 Atlantic hurricane season was the least active season experienced in the Atlantic Basin since 1997. During the 2009 season, activity was below both the 1950–2008 and 1995–2008 averages, with nine named storms, three hurricanes, and two major hurricanes. Although the Atlantic Basin has been in a period of heightened activity since 1995, it is not unusual for below-average activity to occur; the 1997 season exhibited below-average activity, and the years 2002, 2006, and 2007 all exhibited borderline sub-normal to near-normal activity. Three of the four seasons (1997, 2002, and 2006) occurred during El Niño years.

The 2009 season was characterized by a borderline weak-to-moderate El Niño. Despite above-average sea surface temperatures (SSTs) and favorable sea level pressures during the peak season months of August–October, increased vertical wind shear related to El Niño was sufficient to suppress tropical cyclone development and intensification. This heightened wind shear manifested itself most markedly in the dissipation of five of the nine named storms over tropical waters.

Even taking the below-average activity in the 2009 season into account, there is no evidence that the period of heightened hurricane activity in the Atlantic has ceased. Rather, the indication is that reduced cyclonic activity due to El Niño in 1997, 2002, and 2006 has caused the short-term respites from the otherwise elevated levels of activity that have been observed since 1995.

Outlook for the 2010 Hurricane Season

Atlantic hurricane forecasts for the 2010 Atlantic hurricane season are unanimously predicting a return to levels of activity well above the 1950–2009 historical average. The main factors driving these forecasts are anomalously warm SSTs in the Atlantic Main Development Region (MDR) (running between 1.5–2°C above average) and the current El Niño-Southern Oscillation (ENSO)-neutral conditions in the Equatorial Pacific Ocean following the dissipation of the 2009 El Niño.

- Main Development Region SSTs: Since January 2010, the MDR has been characterized by strikingly warm SSTs. April was the third straight month in 2010 where record SSTs were recorded. These exceptionally warm SSTs could have a major impact on the 2010 Atlantic hurricane season.
- El Niño: In May 2010, the Australian Bureau of Meteorology declared that climate indicators across the equatorial pacific became ENSO-neutral (i.e., neither El Niño nor La Niña) and there seems to be an increasing likelihood of a La Niña forming. Should the 2010 Atlantic hurricane season coincide with ENSO-neutral or La Niña conditions in the Pacific, then the main mechanism responsible for inhibiting hurricane activity during the 2009 season—enhanced vertical wind shear—is unlikely to play a major role in suppressing this season’s activity.

RMS Cat Response

The RMS® Catastrophe (Cat) Response service provides timely information and products to help clients assess the potential impact of natural catastrophe events on their own portfolios and on the industry as a whole, on a timescale as close to real-time as possible. For more information on RMS Cat Response and Cat Updates notifications for catastrophe event occurrences around the world, visit https://www.rms.com/Catastrophe/Catupdates/

Impacts of the Deep Water Horizon Oil Spill

The April 20 explosion of the MODU Deepwater Horizon drilling platform in the Gulf of Mexico, located approximately 50 mi (80 km) southeast of Venice, Louisiana, led to the uncontrolled flow of an estimated 12,000 to 19,000 barrels of crude oil a day into the Gulf of Mexico.

Now that hurricane season is underway, the presence of the oil slick in the Gulf raises questions about (a) the impact it could have on tropical cyclone formation or development; (b) the likely impact of a hurricane on the oil slick; and (c) who will be responsible for the clean-up costs if a hurricane washes the oil farther ashore.

While the oil is not expected to play a significant part in altering hurricane activity, a hurricane tracking over the oil has potential to accelerate the biodegradation process, and distribute oil over a wider area (NOAA). In addition, any associated storm surge has the potential to carry oil onto the coastline and inland.

RMS will continue to closely monitor the location of the oil slick through the hurricane season and will provide further information on the likely impacts in RMS Cat Update reports, particularly with regard to any hurricane tracking over or in the vicinity of the oil.

THE 2009 HURRICANE SEASON IN REVIEW

The 2009 Atlantic hurricane season was characterized by a low number of tropical storms and hurricanes. Those that did form were generally short-lived and dissipated before they could make landfall. The 2009 season proved less active compared to both the 1950–2008 average of 10.4 named storms, and the 1995–2008 average of 14.5 named storms. In fact, with a total of only nine named storms, 2009 was the least active season since 1997 (7 named storms) in terms of the number of named storms.

In 2009, three named storms developed into hurricanes, and two developed into major hurricanes (Category 3–5 on the Saffir-Simpson Scale); however, all hurricanes were characterized by relatively short lifespans. During 2009, the total number of named storms, hurricanes, and major hurricanes represented 87%, 48%, and 74%, respectively, of the 1950–2008 average. When assessed against the 1995–2008 average, the corresponding percentages are 62%, 38% and 51%.

Figure 1 shows the 2009 seasonal activity plotted against both the 1950–2008 and 1995–2008 averages.

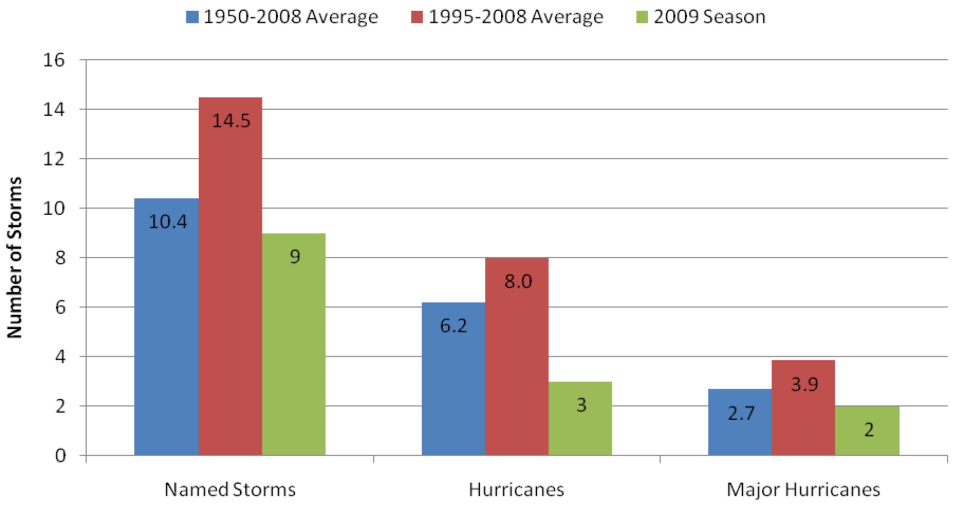

Figure 1: A summary of the 2009 Atlantic Basin tropical storm numbers (green) against the longer (1950–2008, blue) and shorter-term (1995–2008, red) seasonal averages.

The 2009 season had a late start, beginning on August 15 (Table 1), with Ana's formation close to the Cape Verde Islands. This was in contrast to the previous two years where the first named storms were declared in May (Arthur in 2008, Barry and subtropical storm Andrea in 2007). The 2009 season came to a close with the dissipation of Hurricane Ida on November 11.

Table 1: Summary of the 2009 Atlantic Basin tropical storms (TS), hurricanes (H-category) and major hurricanes (MH-category)

Name	Dates	Highest Category
Ana	August 15–16	TS
Bill	August 15–24	MH-4
Claudette	August 16–17	TS
Danny	August 26–29	TS
Erika	September 1–3	TS
Fred	September 8–12	MH-3
Grace	October 5–6	TS
Henri	October 6–7	TS
Ida	November 4–10	H-2

During the 2009 season, only two tropical storms (no hurricanes) made landfall in the Caribbean. In the continental U.S., only two storms made landfall—tropical storms Claudette and Ida. Both made landfall along the Gulf of Mexico Coast, making 2009 the fourth consecutive year in which there were no hurricane landfalls along the U.S. Atlantic coastline. While there is no evidence to suggest a permanent shift in landfalling patterns, this phenomenon has not occurred since the years 1980–1983.

Five of the nine tropical storms that formed during the season (Ana, Danny, Erika, Fred, and Henri) dissipated over tropical waters. Typically, this only happens in years characterized by strong vertical wind shear in the deep tropics (Klotzbach & Gray, 2009b); as was the case in 2009, when strong vertical wind shear was attributed mainly to the moderate development of a borderline weak-moderate El Niño event.

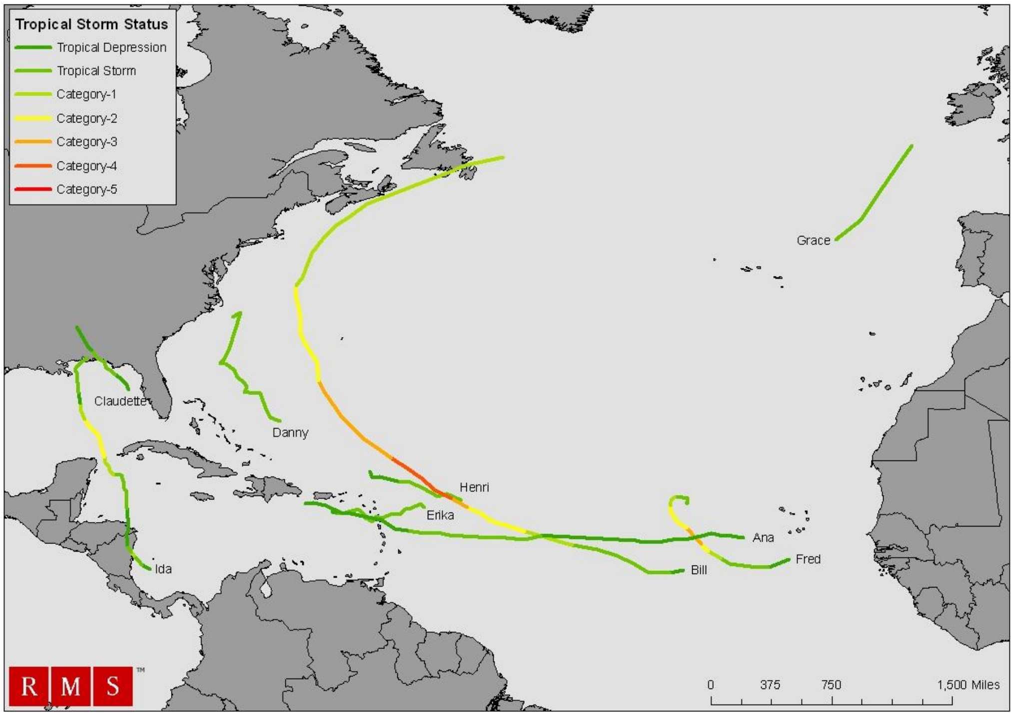

Figure 2: Tracks of the named storms during the 2009 Atlantic Basin hurricane season. Only Bill, Fred, and Ida developed into hurricane-strength storms.

Accumulated Cyclone Energy (ACE)

The Accumulated Cyclone Energy (ACE) index, a measure of total wind energy for basin and landfalling tropical cyclone activity, is used to express the activity of both individual tropical storms and entire tropical cyclone seasons. An individual storm's ACE value is calculated by summing the squares of the maximum sustained wind speed every six hours during its lifetime. Over the course of a hurricane season, the ACE contributions of all storms are added together to produce an estimate of the total activity of the season, taking into account the number, strength, and duration of all storms.

Seasonal ACE totals provide a useful metric for comparing hurricane seasons. Since 1950, the season with the greatest ACE total, 248 units, was 2005 (with 28 tropical storms, 15 hurricanes, and 7 major hurricanes); while the season with the lowest ACE total, 17 units, was 1983 (with 4 tropical storms, 3 hurricanes, and 1 major hurricane).

Of the nine named storms that developed between August–November 2009, Ida reached Category 2 hurricane status, while Fred (Category 3) and Bill (Category 4) reached major hurricane status. The three events contributed almost 90% of the total Accumulated Cyclonic Energy (ACE) for the season (Figure 3). The least intense of the three, Ida, was of sufficient strength and duration (7 days) that it contributed more ACE units to the seasonal total than the remaining six tropical storms combined. Hurricane Bill, with a duration of 10 days, contributed more ACE units than all other tropical storms combined.

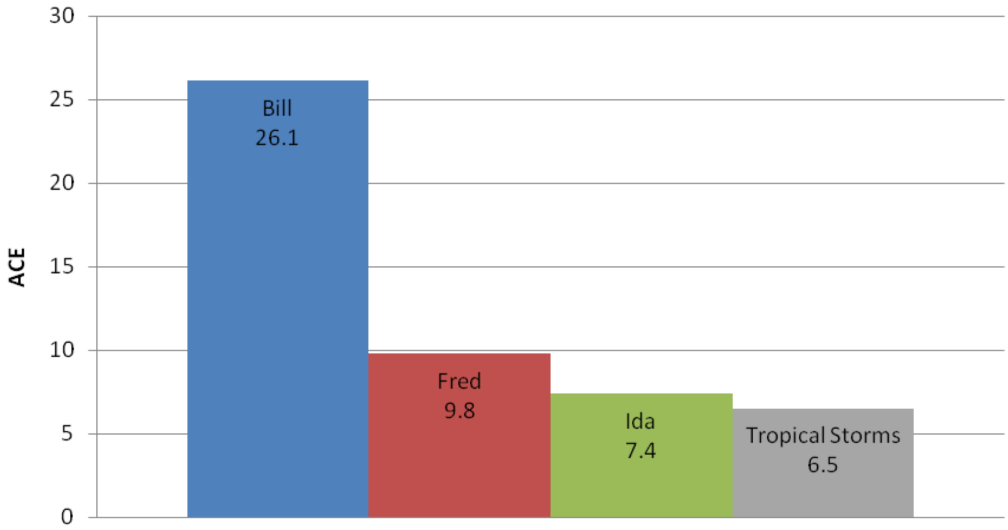

Figure 3: ACE index contributions of Hurricane Ida and major hurricanes Bill and Fred to the total 2009 hurricane season. Combined, these three storms accounted for nearly 90% of the total ACE; the rest is made up from the contributions of the six remaining tropical storms.

Figure 4 shows the seasonal ACE index (Bell et al. 2000) for the current high-activity Atlantic hurricane period that began in 1995 (Goldenberg et al., 2001). The 2009 total ACE index was 60% of the median and approximately 33% of the seasonal average (165% of the median) since 1995. According to the NOAA classification (where "near-normal" seasons are defined as having ACE indices between 75–117% of the median), the 2009 Atlantic hurricane season is only the second season (after 1997) since 1995 to be considered "below normal."

From 1995 onward, 10 out of the 15 Atlantic seasons have been classified as "above normal." This is in stark contrast to the preceding low-activity era from 1971–1994, where 50% of the seasons were below normal, and only three were classified as above normal. Of the five seasons since 1995 considered below normal, four (1997, 2002, 2006, and 2009) correspond to El Niño years (Bell et al., 2010).

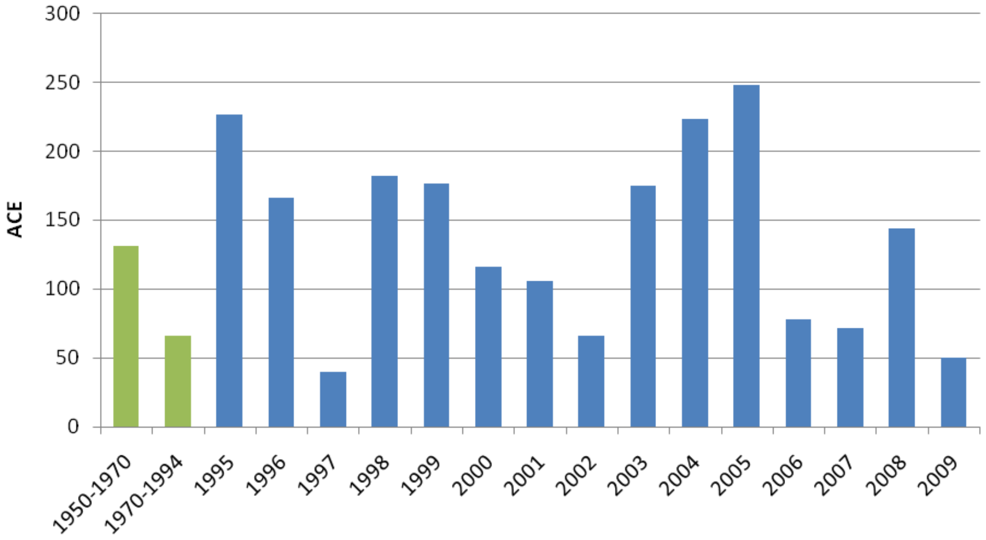

Figure 4: Seasonal ACE values for the years between 1995 and 2009 (blue bars). The 1950–1970 and 1970–1995 averages are shown in green.

The 2009 Atlantic hurricane season was below average in terms of activity and as a result, the impacts of the tropical storms on the countries surrounding the Caribbean Sea were limited. This is in stark contrast to the 2008 season, which resulted in insured losses exceeding $25 billion (Swiss Re, 2008) and over 870 fatalities (NCDC, 2008). Current estimates of the impacts of the 2009 season are of total insured losses on the order of $250 million (SwissRe, 2010; Environment Canada, 2009) and six fatalities.

Review of the 2009 Seasonal Forecasts

The 2009 hurricane season was widely forecast to be less active than the 1995–2008 average (period of heightened activity), but activity was expected to be generally in line with the 1950–2008 average. The below-average activity experienced in 2009 (9 named storms)—even compared to the 1950–2008 average (10.4 named storms)—was somewhat unexpected. Predictions of low tropical cyclone activity were primarily based on two factors: the status of the El Niño Southern Oscillation (ENSO) and predictions of cooler-than-normal sea surface temperatures (SSTs) in the Main Development Region (MDR) of the tropical Atlantic Ocean. Activity predictions made by four major forecasters before the start of the 2009 hurricane season are summarized in Table 2. For comparison, this table also contains the corresponding seasonal averages for the time periods 1950–2008 and 1995–2008.

Seasonal Forecasts

The three main forecasting groups that issue publicly available seasonal forecasts for tropical storms are Colorado State University (CSU), Tropical Storm Risk (TSR) at University College London, and the National Oceanic and Atmospheric Administration (NOAA). Since 2007, the U.K. Met Office has released a publicly available seasonal forecast, and this year predictions by private forecasters AccuWeather and Weather Services International (WSI) are also available to the public.

Tropical Storm Risk (TSR)

The two key factors behind the Tropical Storm Risk forecasts are the predicted trade winds at 925 mb height over the Caribbean Sea and tropical North Atlantic region, and the August–September forecast sea surface temperature for the Atlantic Main Development Region.

Colorado State University (CSU)

The forecasts provided by CSU use a range of methods that include a three-predictor model, analog predictors, and a statistical forecast scheme using past data. Indicators for forecasted activity levels include sea surface temperatures during certain months, sea level pressure for certain months, and number of storm days.

National Oceanic Atmospheric Administration (NOAA)

The NOAA tropical cyclone outlook is based on predictions of large-scale climate factors known to be strong indicators of upcoming seasonal Atlantic hurricane activity. Their prediction takes into account the uncertainties of the El Niño and La Niña forecasts, around the type of storms and hurricanes produced by a certain set of climate conditions or of weather patterns that are unpredictable and may affect the seasonal hurricane activity.

U.K. Met Office

The Met Office uses a dynamical seasonal prediction model called GloSea, which simulates the ocean-atmosphere processes and interactions that determine tropical storm development. One of the key indicators used by the model is the El Niño Southern Oscillation (ENSO), the Met office claims that GloSea has shown good skill in predicting the ENSO cycles.

AccuWeather

In recent years, the private forecaster AccuWeather has been making public forecasts available. As well as providing estimates of the total number of named storms, hurricanes, and major hurricanes, the AccuWeather forecast also attempts to predict the number of storms which will impact the U.S. coastline.

Weather Services International (WSI)

WSI, another private forecaster, has also recently made public forecasts for Atlantic hurricane seasons available. In addition to their activity estimates, WSI has also developed a statistical hurricane landfalling model which considers factors such as northern hemisphere ocean temperatures and prevailing atmospheric patterns.

Table 2: Activity forecasts for the 2009 Atlantic hurricane season issued by Tropical Storm Risk (TSR), Colorado State University (CSU), the Climate Prediction Center (CPC) of the National Oceanographic and Atmospheric Administration (NOAA) and the U.K. Met Office. The 1950–2008 and 1995–2008 averages, along with the 2009 observed activity are listed at the bottom of the table.

	Forecast Month	**Named Storms**	**Hurricanes**	**Major Hurricanes**	**ACE Index**
TSR	April	15.0 (±3.8)	7.8 (±2.6)	3.6 (±1.7)	135
	June	10.9 (±3.3)	5.2 (±2.4)	2.2 (±1.6)	69
	July	11.4 (±3.2)	5.6 (±2.2)	2.4 (±1.6)	80
	August	12.6 (±2.8)	6.5 (±1.7)	2.8 (±1.3)	105
CSU	April	12	6	2	100
	June	11	5	2	85
	August	10	4	2	80
NOAA CPC	May	9-14	4-7	1-3	65–130% of the median
U.K. Met Office	June	6	-	-	60
1950–2008 Average	-	10.4	6.2	2.5	102
1995–2008 Average	-	14.9	8.1	3.9	132
2009 Season	**-**	**9**	**3**	**2**	**50**

2009 Sea Surface Temperatures in the Main Development Region

Figure 5 shows the sea surface temperature (SST) anomalies across the tropical Atlantic in May 2009, shortly before the June forecasts were published. The strong negative anomalies in the eastern tropical Atlantic and to the northeast of the Caribbean Islands were expected to persist into the peak hurricane months of August, September, and October.

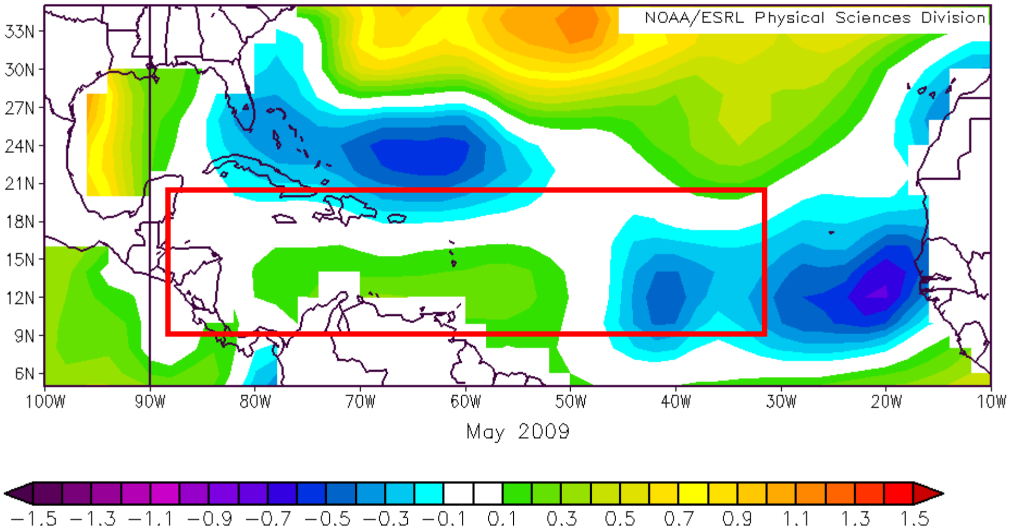

Figure 5: May 2009 SST anomalies in the tropical Atlantic, calculated in relation to the 1968–1996 base period. Red box (here and in subsequent Atlantic plots) denotes the Main Development Region (MDR). Data provided by Kalnay et al., 2006. Image provided by the NOAA/ESRL Physical Sciences Division , Boulder Colorado (http://www.esrl.noaa.gov/psd/).

The early months of the 2009 season (June–July) were characterized by predominantly neutral and slightly positive SST anomalies across most of the Main Development Region (MDR) with negative anomalies in the eastern portion of the MDR (Figure 6).

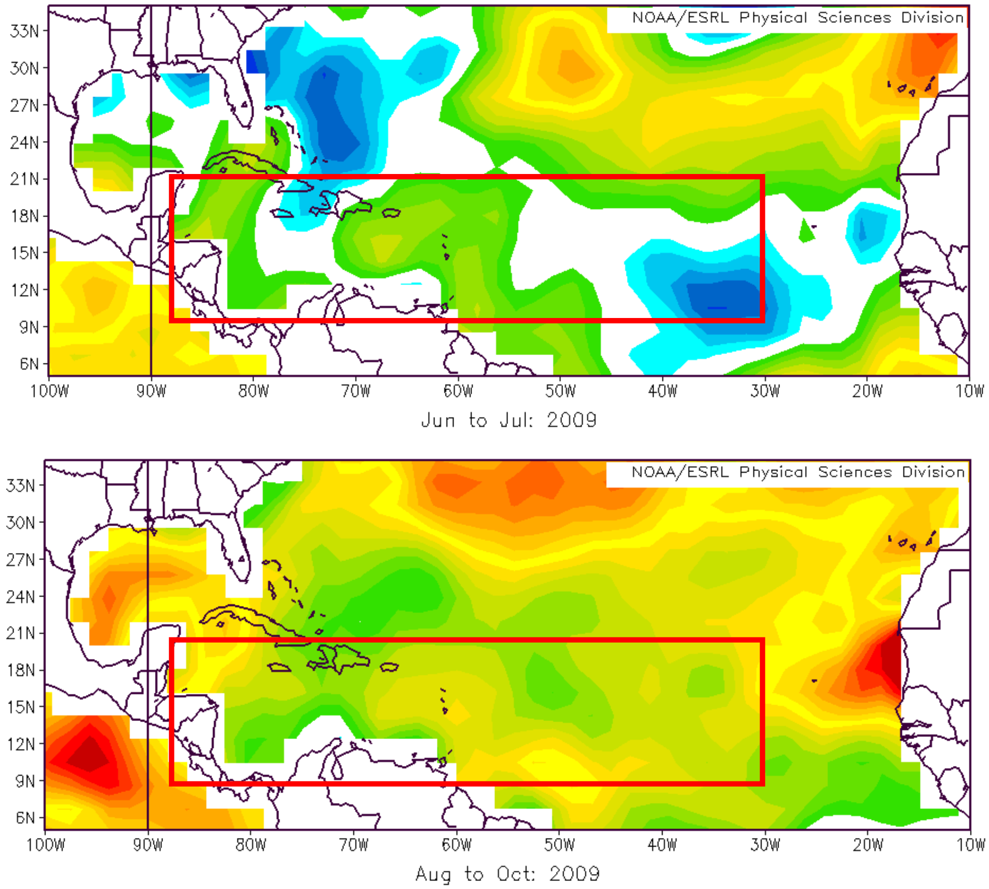

Figure 6: June–July and August–October 2009 sea surface temperatures (SST) Anomalies in the tropical Atlantic. These anomalies are calculated in relation to the 1968-1996 base period. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Website at http://www.esrl.noaa.gov/psd/. Data provided by Kalnay et al., 2006.

These warmer-than-normal SSTs are a continuation of a trend observed since 1995. This period of warmer SSTs has been linked with a period of elevated hurricane activity (Bell et al., 2008); however, 2009 is one of two years in this period where hurricane activity was observed to be lower than normal, despite warmer SSTs. It is clear that the lower-than-normal activity during the peak months of the season, August-September-October (ASO) cannot be attributed to Atlantic SSTs and was likely the result of larger-scale atmospheric anomalies in place.

Despite the anomalously warm SSTs across the MDR for much of the 2009 Atlantic hurricane season, activity was significantly suppressed. Sea level pressures were generally favorable for cyclogenesis, while enhanced vertical wind shear, related to the weak-moderate El Niño acted to hinder tropical cyclogenesis and development.

The State of ENSO during the 2009 Hurricane Season

What is ENSO?

The El Niño Southern Oscillation (ENSO) is the most prominent year-to-year climate fluctuation on Earth (McPhaden, 2004). It originates in the tropical Pacific with unusually warm (El Niño) and unusually cold (La Niña) events recurring approximately every 3–7 years.

During an El Niño event, the trade winds in the central and western Pacific relax, allowing for warmer-than-average surface waters in the eastern tropical Pacific Ocean and a weakened SST gradient across the equatorial Pacific. The eastward displacement of the warm SSTs results in a displacement of the atmospheric circulation, which in turn forces changes in weather patterns across the globe. In normal, non-El Niño conditions, the trade winds blow west across the tropical Pacific.

There is a strong relationship between ENSO and hurricane activity; ENSO can cause large interannual fluctuations in Atlantic hurricanes and major hurricanes through its impacts on the upper level circulation and vertical wind shear in the Main Development Region (MDR) (Gray, 1984). All other factors being equal, La Nina episodes typically favor hurricane development by reducing the vertical wind shear across the MDR—the opposite effect on the prevailing atmospheric conditions to El Niño.

During the winter of 2008–2009, La Niña conditions prevailed, leading to negative sea surface temperature anomalies in the eastern Pacific. These anomalies began moderating through the early part of 2009, initially becoming ENSO-neutral, before turning positive in the summer and continuing into the fall.

Table 3 lists the 2009 NINO3.4 anomalies for the months of January, April, July and October.

Table 3: 2009 NINO3.4 anomalies for January, April, July and October (from Klotzbach & Gray, 2009b).

Month	Anomaly
January	-1.0
April	-0.2
July	+0.9
October	+1.0

Vertical wind shear in the tropical Atlantic was the primary factor suppressing tropical cyclone activity during the 2009 Atlantic hurricane season. High vertical wind shear over the Atlantic Basin is a common effect of El Niño (Gray, 1984; Knaff, 1997; Goldenberg and Shapiro, 1996; Bell and Chelliah, 2006) and has been observed during the recent El Niño years of 1997 (which recorded the lowest number of named storms since 1995) and 2002 (Bell et al., 2010).

OUTLOOK FOR 2010 ATLANTIC HURRICANE ACTIVITY

At the start of the 2010 Atlantic hurricane season, all seasonal forecasts are calling for an above-average hurricane season in terms of the number of named storms, hurricanes, and major hurricanes in comparison to both the 1950–2009 and 1995–2009 averages. This section provides an overview of the December, April, and June seasonal forecasts from various groups and examines the status of some of the environmental factors that may play a part in the activity levels of the 2010 season. The section concludes with a discussion of the skill of seasonal hurricane activity forecasts.

Seasonal Forecasts

Table 4 summarizes the hurricane forecasts released to the public by the start of June. All forecasters are unanimously predicting a return to levels of hurricane activity typical of years during the so-called "active-era" since 1995. There is broad consistency across the recent May and June forecasts with TSR, CSU, WSI, and AccuWeather calling for approximately 16–18 named storms, 10 hurricanes, and 5 major hurricanes. The NOAA CPC forecast is also in good agreement with these predictions.

Table 4: 2010 Atlantic hurricane activity forecasts as of the start of June. The NOAA CPC forecast ranges are for a 70% chance of occurrence.

	Forecast Date	Named Storms	Hurricanes	Major Hurricanes	ACE Index
Tropical Storm Risk (TSR)	Dec 2009	13.9 (±4.9)	7.4 (±3.1)	3.4 (±1.8)	135 (±59)
	Apr 2010	16.3 (±4.1)	8.5 (±2.8)	4.0 (±1.7)	159 (±58)
	Jun 2010	17.7 (±3.5)	9.5 (±2.5)	4.4 (±1.5)	182 (±48)
Colorado State University (CSU)	Dec 2009	11-16	6-8	3-5	100-162
	Apr 2010	15	8	4	150
	Jun 2010	18	10	5	185
WSI	Jan 2010	13	7	3	-
	Apr 2010	16	9	5	-
	May 2010	18	10	5	-
AccuWeather	Apr 2010	15	5	2-3	-
	May 2010	16-18	10-11	5	-
NOAA Climate Prediction Center (CPC)	May 2010	14-23	8-14	3-7	-
1950–2009 Average	-	10.4	6.2	2.7	101
1995–2009 Average	-	14.3	7.7	3.2	139

While the projected number of named storms and hurricanes is not as high as the highly active year 2005, which saw a total of 27 named storms, 15 of which became hurricanes, the projected activity is in line with the amount of activity seen in other active years such as 1995 (with 19 named storms, of which 11 became hurricanes) and 2008 (with 16 named storms, of which 8 became hurricanes).

TSR and CSU are the only forecast groups to predict ACE totals for the season; their June predictions are in very close agreement, indicating that the ACE will be considerably higher than both the 1950–-2009 and 1995–2009 seasonal averages.

If the projected number of named storms and ACE values holds true, 2010 has the potential to rank among the most active seasons on record.

El Niño/Southern Oscillation and SSTs

Seasonal forecasts refer to forecasts for lead times ranging from 60 days or a few months to a year ahead. While individual hurricanes cannot be predicted at this timescale, hurricane activity depends strongly on the climatological oceanic and atmospheric conditions and it this large scale climate variability on different timescales that is used to forecast hurricane activity. In the North Atlantic, tropical cyclone activity has a strong relationship with the El Niño Southern Oscillation (ENSO), which shows variability on a timescale of 3–7 years. The variability in sea surface temperatures in the Main Development Region (MDR) is mainly driven by the Atlantic Multidecadal Oscillation (AMO) on decadal timescales. For a review of the relevant climatological factors on different times scales, see Carmago et al. (2009).

The key factors driving above-average projections for activity during the 2010 season are:

- The return, in May, to ENSO-neutral conditions following the weak-moderate El Niño that prevailed during the 2009 season; and the possibility that La Niña conditions may develop during the 2010 season
- Anomalously warm and record-breaking Atlantic SSTs observed in the MDR during the first half of 2010 and the expected continuation of warm SSTs during the 2010 season

The current status of the El Niño and the Atlantic SSTs and their likely impact on the 2010 hurricane season is examined below.

The Role of ENSO on 2010 Atlantic Hurricane Activity

Model forecasts for ENSO heavily influence the level of hurricane activity expected by forecasting groups prior to and during the season. A shift in the model forecasts to indicate either warmer or cooler sea surface temperatures (SSTs) in the Pacific will usually result in either an upward or downward revision of the number of tropical storms and hurricanes expected to form during the course of the season.

At the start of 2010, SSTs were well above-average through the central and equatorial Pacific, indicative of moderate El Niño conditions. But, as 2010 has progressed, initial El Niño conditions have moderated; during May, the Australian Bureau of Meteorology declared that climate indicators across the equatorial pacific became ENSO-neutral[1] (i.e., neither El Niño nor La Niña) and there seems to be an increasing

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[1] http://www.bom.gov.au/climate/enso/

likelihood of a La Niña forming. Historically, about 35–40% of El Niño events are followed by La Niña within the same year.

Figure 7 shows a number of dynamical and statistical model forecasts of the likely progression of the NINO3.4 SST anomaly through the coming hurricane season. While there is considerable spread across the forecasts, all models predict the NINO3.4 anomaly to be below 0.5°C during 2010. While predictions of ENSO tend to have a low skill level, particularly during the spring when there is a so called “spring barrier” to the forecasts, most models indicate a return to El Niño conditions is unlikely, but the onset of La Niña conditions is possible.

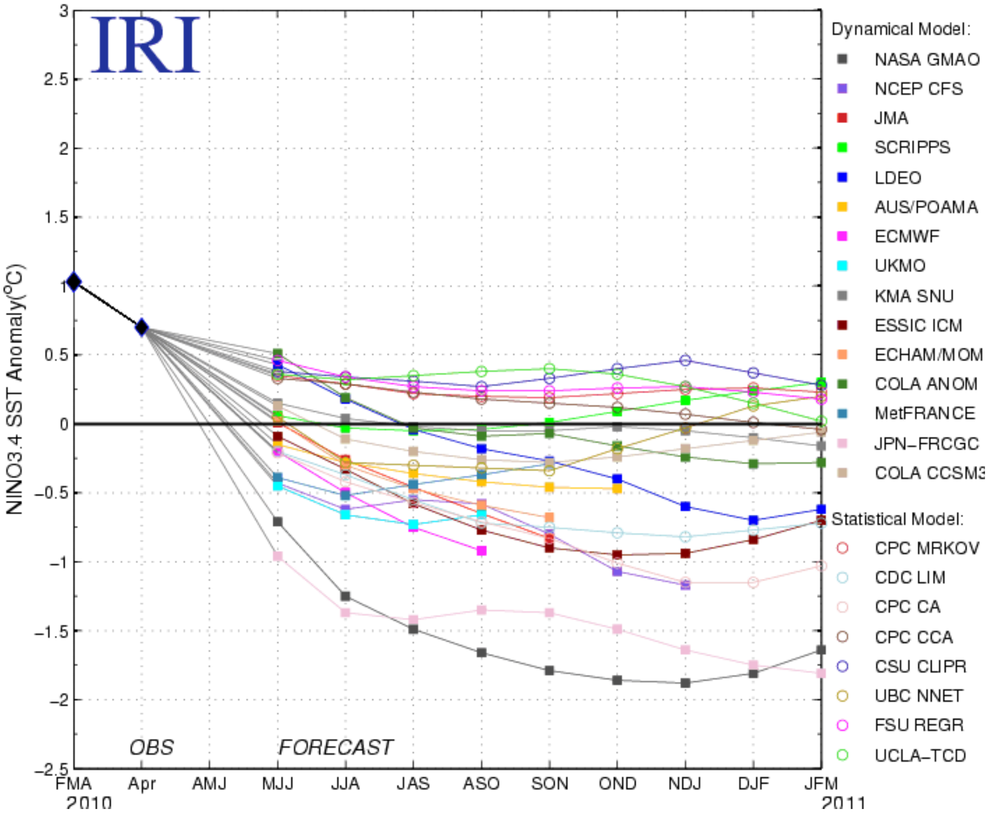

Figure 7: ENSO Model forecasts of the NINO3.4 SST anomaly from May 2010. (Figure courtesy of the International Research Institute for Climate and Society.)

The May International Research Institute for Climate and Society (IRI) probabilistic ENSO forecasts for the NINO3.4 region are shown in Table 5. According to this table, the probability of El Niño conditions returning during the 2010 season is only 3–7% and the probability of La Niña conditions forming becomes increasingly likely as the season progresses, with a 42% likelihood during the peak months (ASO) of the hurricane season.

A weekly NINO3.4 SST anomaly at the end of May was recorded as -0.1°C, a considerable decrease from the April average of 0.7°C, showing that currently this region is in a state of transition.

Table 5: IRI probabilistic ENSO forecast for the NINO3.4 region up to December 2010. Data courtesy of the International Research Institute for Climate and Society.

Season	La Niña	Neutral	El Niño
MJJ 2010	13%	80%	7%
JJA 2010	33%	62%	5%
JAS 2010	40%	57%	3%
ASO 2010	42%	55%	3%
SON 2010	42%	55%	3%
OND 2010	42%	55%	3%

During prevailing El Niño conditions, vertical wind shear across the MDR tends to be heightened and acts to suppress tropical cyclogenesis and development. In contrast, ENSO-neutral and La Niña years are generally associated with very low levels of wind shear and can lead to heightened activity.

Should the 2010 Atlantic hurricane season coincide with ENSO-neutral or La Niña conditions in the Pacific, then the main mechanism responsible for inhibiting hurricane activity during the 2009 season—enhanced vertical wind shear—is unlikely to play a major role in suppressing this season's activity. Thus, it is important to understand other factors that could have a dominant role in influencing the upcoming season's activity.

Sea Surface Temperatures

By the end of May 2010, SST anomalies in the Atlantic MDR were running up to 1.5°C above average.

Since January 2010, the Main Development Region (MDR) has been characterized by strikingly warm SSTs (Figure 8). The increasingly warm anomalies recorded over the last few months are a key factor in the current forecasts for an above-average 2010 hurricane season. According to the U.K. Met Office's Hadley Center, the April SST anomaly of 1.46°C in the Atlantic MDR was the highest on record for the month of April. April was the third straight month in 2010 where record SSTs were recorded, beating the previous records set in June 2005 and March 2010 by 0.2°C (Masters, 2010).

The exceptionally warm SSTs could have a major impact on the 2010 Atlantic hurricane season. High SST anomalies were observed in March of 1958, 1969, and 2005—all seasons in which five or more major hurricanes (Category 3 or greater) occurred (Masters, 2010). The average activity for these three seasons is 15 named storms, 11 hurricanes, and 6 major hurricanes. During the 1969 Atlantic hurricane season there was a weak El Niño prevalent, yet the season still yielded 18 named storms, 12 hurricanes, and 5 major hurricanes.

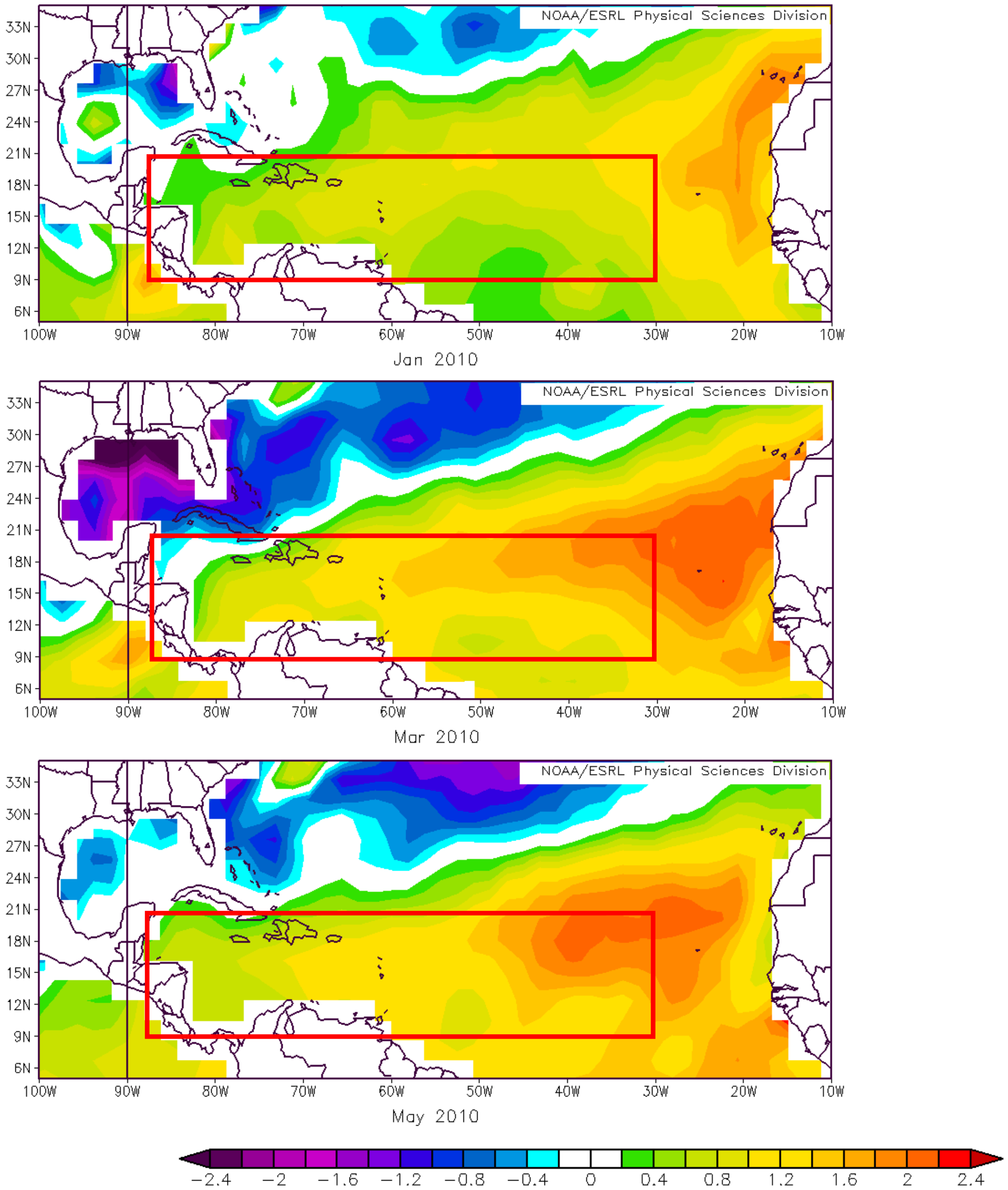

Figure 8: Atlantic SST anomaly composites for the months of January, March, and May 2010. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado (http://www.esrl.noaa.gov/psd/). Data provided by Kalnay et al., 2006.

The high SSTs observed in 2010 are due to the influence of the Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO)—climate patterns in the North Atlantic Ocean related to variations in sea level pressure between the Icelandic Low and the Azores High. Between December and February, the sea level pressure difference was small because the Azores High was weaker than normal. This led to reduced trade winds over the tropical Atlantic, which in turn resulted in less mixing of the surface waters with deeper, cooler waters, as well as less evaporational cooling of the surface water (Masters, 2010), thus allowing sea surface temperatures to rise. This anomaly associated with the NAO has occurred in combination with the warm phase of the Atlantic Multidecadal Oscillation (AMO) that began in 1995, and has been one of the driving forces for the high levels of Atlantic hurricane activity seen since 1995.

CSU, TSR, and NOAA cite the state of tropical Atlantic SSTs as key reasons for their predictions of above-average hurricane activity during 2010. However, despite the MDR SSTs being well above-average in the run-up to hurricane season, it will be the temperatures during hurricane season, most notably the peak months of August and September, that have the biggest potential to impact hurricane activity. TSR is calling for August–September SSTs to be 0.42±0.27°C warmer than average, indicating that the warm SSTs observed in recent months could continue.

Skill of Seasonal Forecasts

As discussed above, seasonal forecasts of hurricane activity largely depend on the strength of the relationship between certain climatological factors and hurricane activity, as well as the successful prediction of the climatological factors themselves. Forecast methodologies and the climatological factors (predictors) used have changed frequently over the years, indicating that the uncertainties remain high in this area of research. The changes in methodologies also mean that there are only small sample sets available to evaluate the performance of any particular approach. Therefore, the predictive skill of the forecasts is often established through back-testing historical data using the most recent forecast methodologies, through cross validation (see, for example, Klotzbach and Gray, 2009c)

The skill of a forecast is measured in comparison to a simple benchmark forecast—for example the historical average number of hurricanes making landfall. Sometimes a running mean over a smaller number of recent years is used as a benchmark instead. To be skillful, the actual forecast needs to beat the benchmark forecast statistically significantly.

Depending on the forecast lead time, seasonal forecasts have more or less skill. It has been shown that seasonal forecasts issued in December and April, prior to the season, have hardly any forecast skill (Carmargo et al., 2007); while early June and early August seasonal forecasts show some modest skill (see, for example, Klotzbach & Gray, 2009c, Blake et al., 2010 and Owens & Landsea, 2003). While this modest skill appears to be statically significant it is still questionable if forecasts with such large uncertainty are useful for any business decisions related to the insurance industry. Therefore, RMS strongly recommends using seasonal hurricane activity forecasts with caution.

Impact of the Deep Water Horizon Oil Spill during the 2010 Hurricane Season

On April 20, a blowout occurred on the Macondo well in the Gulf of Mexico, causing an explosion and fire on the MODU Deepwater Horizon drilling platform, located approximately 50 mi (80 km) southeast of Venice, Louisiana. The blowout led to the uncontrolled flow of an estimated 12,000 to 19,000 barrels of crude oil a day into the Gulf of Mexico. There have been several failed attempts to stop the flow, but the most recent attempt, dubbed “Top Hat,” is showing some success in capturing 50% or more of the release as of June 7. However, oil is likely to continue to leak until August, when BP plans to intercept and block the well with a new borehole close to the depth of the underlying reservoir. On June 7, 48 days after the explosion, estimates for the amount of oil spilled thus far range from 550,000 to more than a million barrels. Satellite imagery shows that the oil covers about 3% of the area of the Gulf of Mexico.

Now that hurricane season is underway, the presence of the oil slick in the Gulf of Mexico raises questions about (a) the impact it could have on tropical cyclone formation or development (b) the likely impact of a hurricane on the oil slick and (c) who will be responsible for the clean-up costs if a hurricane washes the oil farther ashore.

NOAA describes the likely impact of the oil on a hurricane and the effects of a hurricane on the oil spill in NOAA's Oil Spill Response: Hurricanes and the Oil Spill. The oil spill covers a small portion of the Gulf of Mexico and is fairly patchy in nature, except for immediately near the source. This means that any developing storm will still likely retain enough contact with the sea surface to draw energy for development and will unlikely be majorly impacted. For any storm tracking over the oil, providing the slick remains small in comparison to a typical hurricane's general environment and size, there is not expected to be any significant impact on the intensity or track of a storm. While the oil is not expected to play a significant part in altering hurricane activity, a hurricane tracking over the oil has potential to accelerate the biodegradation process, and distribute oil over a wider area (NOAA). In addition, any associated storm surge has the potential to carry some of the oil into the coastline and inland.

It is too early to assess the full financial cost of the oil spill but so far BP estimates it has already spent $1.25 billion on efforts to contain the spill, and has been paying thousands of claims for associated damages from the oil spill. As of Monday, 7 June BP had paid out over 37,000 claims to a variety of businesses and property owners, totaling over $48 million. While BP has stated that they will pay for any damage associated with the oil spill, the question of individual compensation for pollution damage and loss of revenue is likely to become exceptionally complicated in the aftermath of a storm. Estimates of insured losses associated with the disaster range from $1.4–3.5 billion, reflecting the total limits of the liability insurance coverage of the parties directly connected with the equipment and operation of the Macondo well. While BP (owner of 65% of the field) is self insured, the other parties, Anadarko (with 25%) and Mitsui Oil Corp (with 10%), have purchased liability coverage that is expected to be exhausted.

RMS will continue to closely monitor the location of the oil slick through the hurricane season and will provide further information on the likely impacts in RMS Cat Update reports, particularly with regard to any hurricane tracking over or in the vicinity of the oil.

RMS CAT RESPONSE FOR THE 2010 ATLANTIC HURRICANE SEASON

The RMS® Catastrophe (Cat) Response service offers around-the-clock monitoring of global catastrophes, regular updates on active events, and access to all information released through the Cat Updates webpage on the RMS website at www.rms.com.

What are Cat Updates?

RMS Cat Updates is a dedicated service that provides clients with timely information and products to assess the potential impact of catastrophe events—such as hurricanes, extra-tropical storms, tornadoes, earthquakes, and floods—on their own portfolios and on the industry as a whole, on a timescale as close to real-time as possible. RMS client Cat Updates are accessible from the Client Resources area of the RMS website (www.rms.com).

RMS also provides publicly available versions of its Cat Updates at https://www.rms.com/Catastrophe/Catupdates/.

For the Atlantic hurricane season, RMS' dedicated Cat Updates service begins tracking an event once it is declared a named storm. Once a storm reaches hurricane status and is forecast to make landfall in the U.S. or impact any Caribbean Islands, RMS begins issuing full Cat Update reports. Modeling parameters are released when a hurricane is 48 hours from a U.S. landfall or has impacted any Caribbean Islands.

As a service to subscribing clients, RMS offers email notifications and Web updates for catastrophe event occurrences around the world. The RMS catastrophe response team monitors global windstorm, earthquake, and other hazard activity 24 hours a day, 7 days a week, and notifies clients of significant event occurrences before and after they strike. Emphasis is placed on events of sufficient intensity to cause insurance loss in regions covered by RMS models, as well as major humanitarian or economic disasters.

Cat Updates help RMS clients respond more effectively to impending or recent catastrophic events. The updates include details on event characteristics and location, parameters for simulating a scenario event in RiskLink® software, and the RMS perspective on exposures at risk, impacts, and losses. RMS also provides industry loss estimates using our catastrophe modeling technology and exposure databases, combined with up-to-the-minute event data. Scientific analysis of the event, and damage reports are available to all through our publicly available website.

The RMS catastrophe response team posts current information to the RMS website at least once a day when responding to events or tracking potential threats. Email notifications are sent to clients when new information is posted. RMS clients can access the full Cat Updates postings in the client resources area of the RMS website.

RiskOnline® Internet Service

RMS clients can also track hurricane loss estimates online in real-time using RMS' online automated hurricane loss estimation service, RiskOnline.

RiskOnline allows clients to track hurricane loss estimates in real-time as storms approach the U.S. Estimates can be tracked against the RMS industry exposure database or individual client portfolios. Often the first loss assessment tool available following storm formation, RiskOnline is fully automated and activates as soon as the National Hurricane Center (NHC) names a storm—either when the storm's pressure drops below 995 mb or the storm is west of 58°W longitude. RiskOnline then begins selecting stochastic tracks from the RMS® U.S. Hurricane Model event set and generates losses based on the track selections, allowing clients to access probabilistic loss estimates. Results can be viewed online at www.riskonline.com, offering subscribing clients secure, around-the-clock access to the overall distribution of potential expected losses.

RiskOnline is synchronized with Cat Updates from 48 hours before expected landfall, as soon as the manually selected suites of stochastic events are released. From this time, the automatic track selections in RiskOnline are replaced with the manually selected tracks. Clients who have uploaded RDMs to RiskOnline can effectively automate the STEP tool process using the RiskOnline service.

The benefits of using RiskOnline include:

- Automated analyses of RMS Industry Loss Curves (ILCs) or company-specific RDMs
- Transparent and comprehensive probabilistic loss forecasting
- Event updates every six hours prior to 48 hours before landfall, after which the manually selected stochastic event selections released by RMS via Cat Updates are inserted into RiskOnline
- Convenient, online access to loss estimates
- Synchronization with RMS Cat Updates, as noted in point 3

For more information about RiskOnline, visit http://www.rms.com/Catastrophe/Software/RiskOnline.asp.

REFERENCES

Avila, L. A., 2009: Tropical Cyclone Report, Hurricane Bill. http://www.nhc.noaa.gov/pdf/TCR-AL032009_Bill.pdf

Avila, L. A. and J. Cangialosi, 2010: Tropical Cyclone Report, Hurricane Ida. http://www.nhc.noaa.gov/pdf/TCR-AL112009_Ida.pdf

Bell, G. D., Halpert, M. S., Schnell, R. C., Higgins, R. W., Lawrimore, J., Kousky, V. E., Tinker, R., Thiaw W., Chelliah, M. and A. Artusa, 2000: Climate Assessment for 1999. *Bull. Amer. Meteor. Soc.*, **81**(6), 1328-1328.

Bell, G., Blake, E., Landsea, C., Chelliah, M., Pasch, R., Mo, K. and S. Goldenberg, 2006: The 2006 North Atlantic Hurricane Season: A Climate Perspective. *State of the Climate in 2006*. A. M. Waple and J. H. Lawrimore, Eds. *Bull. Amer. Meteor. Soc.*, **87**,

Bell, G. D., and M. Chelliah, 2006: Leading tropical modes associated with interannual and multi-decadal fluctuations in North Atlantic hurricane activity. *J. of Climate*. **19**, 590-612.

Bell, G., E. Blake, T. Kimberlain, J. Gottschalck, C. Landsea, R. Pasch, J. Schemm and S. Goldenberg, 2010: The 2009 North Atlantic Hurricane Season: A Climate Perspective. http://www.cpc.noaa.gov/products/expert_assessment/hurrsummary_2009.pdf

Berg, R., 2009: Tropical Cyclone Report, Tropical Storm Grace. http://www.nhc.noaa.gov/pdf/TCR-AL092009_Grace.pdf

Beven II, J. L., 2010: Tropical Cyclone Report, Tropical Storm Danny. http://www.nhc.noaa.gov/pdf/TCR-AL052009_Danny.pdf

Blake, E. S., 2009a: Tropical Cyclone Report, Tropical Cyclone Ana. http://www.nhc.noaa.gov/pdf/TCR-AL022009_Ana.pdf

Blake, E. S., 2009b: Tropical Cyclone Report, Tropical Cyclone Henri. http://www.nhc.noaa.gov/pdf/TCR-AL102009_Henri.pdf

Brown, D. P., 2009: Tropical Cyclone Report, Tropical Storm Erika. http://www.nhc.noaa.gov/pdf/TCR-AL062009_Erika.pdf

Blake et al., 2010: Verification of 12 years of NOAA Atlantic seasonal hurricane forecasts, 29th Conference on Hurricanes and Tropical Meteorology: http://ams.confex.com/ams/29Hurricanes/techprogram/paper_167939.htm

Burpee, R.W., 1972: The origin and structure of easterly waves in the lower atmosphere of North Africa. J. Atmos. Sci., **29**, 7-90

Camargo, S. J., A. H. Sobel, A. G. Barnston, and P. J. Klotzbach, 2009: The influence of natural climate variability on tropical cyclones and seasonal forecasts of tropical cyclone activity, in Global Perspectives on Tropical Cyclones, World Scientific, 2nd edition, edited by Chan, J. C. L. and Kepert, J. D.

Carmago, S. J. et al., 2007: Seasonal tropical cyclone forecasts, *WMO Bull.*, **56**, 297-309.

East Hampton Star, 2009: http://www.easthamptonstar.com/dnn/Home/News/FundsSoughtforDamage/tabid/10705/Default.aspx

Environment Canada, 2009: Canada's Top Ten Weather Stories for 2009, http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=EA4C0989-1

Gray, W. M., 1984: Atlantic seasonal hurricane frequency: Part I: El Niño and 30-mb quasi-biennial oscillation influences. *Mon. Wea. Rev*., **112**, 1649-1668.

Goldenberg, S.B. and L.J. Shapiro, 1996: Physical mechanisms for the association of El Niño and West African rainfall with Atlantic major hurricane activity. *J. Climate*, **9(6)**, 1169-1187.

Goldenberg, S. B., C. W. Landsea, A. M. Mestas-Nuñez, and W. M. Gray, 2001: The recent increase in Atlantic hurricane activity: Causes and implications. *Science*, **293**, 474-479.

IFRC 2008: Cuba: Hurricane Season 2008 http://www.ifrc.org/docs/appeals/08/MDRCU001.pdf

IRI, 2010a: http://iri.columbia.edu/climate/ENSO/currentinfo/archive/201002/technical.html

IRI, 2010b: http://iri.columbia.edu/climate/ENSO/currentinfo/archive/201003/technical.html

IRI, 2010c: http://iri.columbia.edu/climate/ENSO/currentinfo/archive/201004/technical.html

IRI, 2010d: http://iri.columbia.edu/climate/ENSO/currentinfo/archive/201005/technical.html

Kalnay, E. and Coauthors, 1996: The NCEP/NCAR Reanalysis 40-year Project. *Bull. Amer. Meteor. Soc.*, **77**, 437-471.

Klotzbach, P. J. and W. M. Gray, 2009a: Extended range forecast of Atlantic seasonal hurricane activity and landfall strike probability for 2009. http://hurricane.atmos.colostate.edu/forecasts/2009/june2009/jun2009.pdf

Klotzbach, P. J. and W. M. Gray, 2009b: Summary of 2009 Atlantic Tropical Cyclone Activity and Verification of author's seasonal and 15-day forecasts. http://hurricane.atmos.colostate.edu/forecasts/2009/nov2009/nov2009.pdf

Klotzbach, P. J. and W. M. Gray, 2009c: Twenty-five years of Atlantic Basin seasonal hurricane forecasts (1984-2008), *Geophys. Res. Lett.*, **36**, L09711.

Knaff, J. A., 1997: Implications of summertime sea level pressure anomalies in the tropical Atlantic Region. *J. Clim.*, **10**, 789-804.

Masters, J., 2010: http://www.wunderground.com/blog/JeffMasters/comment.html?entrynum=1480

McGillivray, G., 2010: Annus Horribilis, The Sequel, Institute for Catastrophic Loss Reduction, http://www.iclr.org/images/Annus_horriblis_Two_nat_cats_2009.pdf

McPhaden, M.J, 2004: Evolution of the 2002/2003 El Niño. *Bulletin of the American Meteorological Society*, **85**, 677-692

National Weather Service, 2009: http://www.webcitation.org/5j6Fmea4A

NCDC, 2008: http://www.ncdc.noaa.gov/oa/climate/research/2008/hurricanes08.html#top

NCDC, 2009: http://www.ncdc.noaa.gov/oa/climate/research/2009/hurricanes09.html#top

Owens, B.F. and C.W. Landsea, 2003: Assessing the skill of operational Atlantic seasonal tropical cyclone forecasts. *Weather and Forecasting*, **18**, 45-54.

Pasch, R. J., 2010: Tropical Cyclone Report, Tropical Storm Claudette. http://www.nhc.noaa.gov/pdf/TCR-AL042009_Claudette.pdf

Saunders, M. and Lea, A., 2009: June Forecast Update for Hurricane Activity in 2009, 4th June 2009

Shapiro, L. J., and S. B. Goldenberg, 1998: Atlantic sea surface temperatures and tropical cyclone formation. *J. Climate*, **11**, 578-590.

Swiss Re, 2009: Natural catastrophes and man-made disasters in 2008: North America and Asia suffer heavy losses. Sigma Report No. 2.

Swiss Re, 2010: Natural catastrophes and man-made disasters in 2009: catastrophes claim fewer victims, insured loses fall. Sigma Report No. 1.

LIST OF FIGURES

LIST OF TABLES