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Energy Information Administration

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Short-Term Energy Outlook Supplement:
The 2007 Outlook for Hurricane Impacts on Gulf of Mexico Crude Oil and Natural Gas Production

Highlights

- The National Oceanic and Atmospheric Administration (NOAA) predicts above-normal hurricane activity in the May 22, 2007 version of its *Atlantic Hurricane Season Outlook.* They project 13 to 17 named storms will form within the Atlantic Basin, including 7 to 10 hurricanes of which 3 to 5 will be intense.[1]

- Above-normal hurricane activity in the Atlantic is likely to correspond to increased impacts on offshore crude oil and natural gas producers in the Gulf of Mexico. However, the likelihood of a repeat of the destruction caused by Hurricanes Katrina and Rita in 2005 is relatively small.

- Based on the results of a Monte Carlo hurricane outage simulation, which is conditional on how NOAA's most recent predictions for the level of Atlantic basin hurricane activity compare to historical activity, we expect a total of about 13.2 million barrels (bbls) of crude oil and 86.5 billion cubic feet (bcf) of natural gas to be shut in during the 2007 hurricane season.

- Our simulation results indicate a 1.3-percent probability of more than 100 million bbls of crude oil and/or 600 bcf of natural gas being shut-in during the 2007 hurricane season, similar to the cumulative impact of Hurricanes Katrina and Rita in 2005. Conversely, we project a 2.2-percent chance that offshore Gulf of Mexico production will be unaffected this year as it was during last year's hurricane season.

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[1] http://www.cpc.noaa.gov/products/outlooks/hurricane.shtml

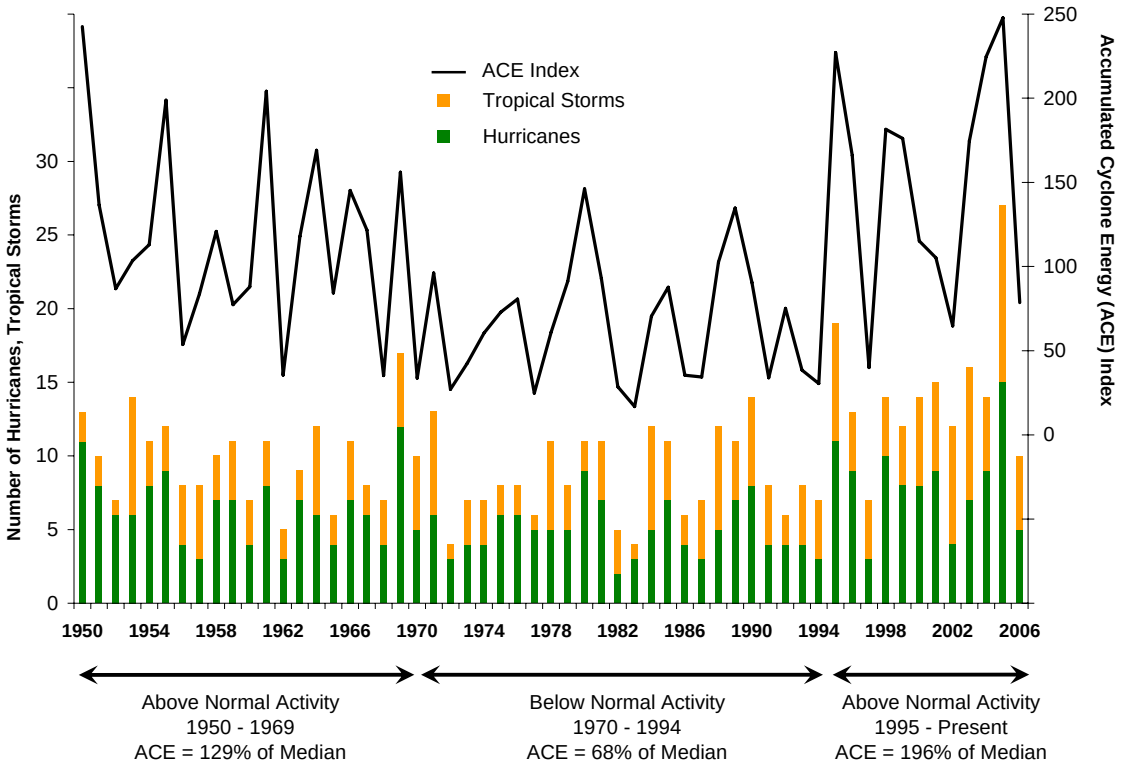
Atlantic Basin Hurricane Activity

The Atlantic Basin hurricane season officially runs from June 1 through November 30. Wind speed is the primary instrument for classifying the power of a given system. In the United States, hurricanes are categorized on the Saffir-Simpson scale by maximum sustained wind speed: Category 1 (74-95 mph), Category 2 (96-110 mph), Category 3 (111-130 mph), Category 4 (131-155 mph), and Category 5 (156+ mph). Tropical storms are weather systems with a maximum sustained wind between 39 mph and 73 mph. Category 3, 4, and 5 hurricanes are usually referred to as intense or major hurricanes, about 75 percent of which occur during the months of August and September. In addition to the standard classification by tropical storm or hurricane wind-speed category, NOAA also describes the intensity of tropical weather systems using its Accumulated Cyclone Energy (ACE) index, which measures the intensity of the wind within a system and the system's duration. Specifically, it is defined as the sum of the squared maximum sustained wind speeds (in knots) for all 6-hour intervals while the weather system is classified as either a tropical storm or hurricane. The ACE index can be used to describe the intensity of particular storms or to describe the collective intensity of a hurricane season (as the sum of ACE indices for all storms).

Figure 1 shows the annual number of tropical storms and hurricanes that occurred within the Atlantic Basin along with the Atlantic ACE index for 1950 through 2006. During this period, an average of 10.3 named storms have passed through the Atlantic each season, including an average of 4.1 tropical storms and 6.2 hurricanes, of which 2.7 were intense. For the entire period, the normal (median) ACE index value, which measures overall hurricane activity, was 89. During the 1950s and 1960s, hurricane activity was above normal, while activity was below normal from the 1970s through the early 1990s. Since 1995, the Atlantic has again been experiencing above-normal activity, with an ACE index almost twice the median value for the entire period. Hurricane researchers refer to this pattern as the "multidecadal cycle" in which seasonal hurricane activity is generally similar over a certain time period. This is one reason hurricane forecasters expect strong tropical weather to continue over the next 5 to 10 years.

NOAA's May 22, 2007 version of its *Atlantic Hurricane Season Outlook* predicts 13 to 17 named storms will form within the Atlantic Basin, including 7 to 10 hurricanes of which 3 to 5 will be intense. These projections correspond to a

Figure 1. Atlantic Basin Hurricane & Tropical Storm Activity

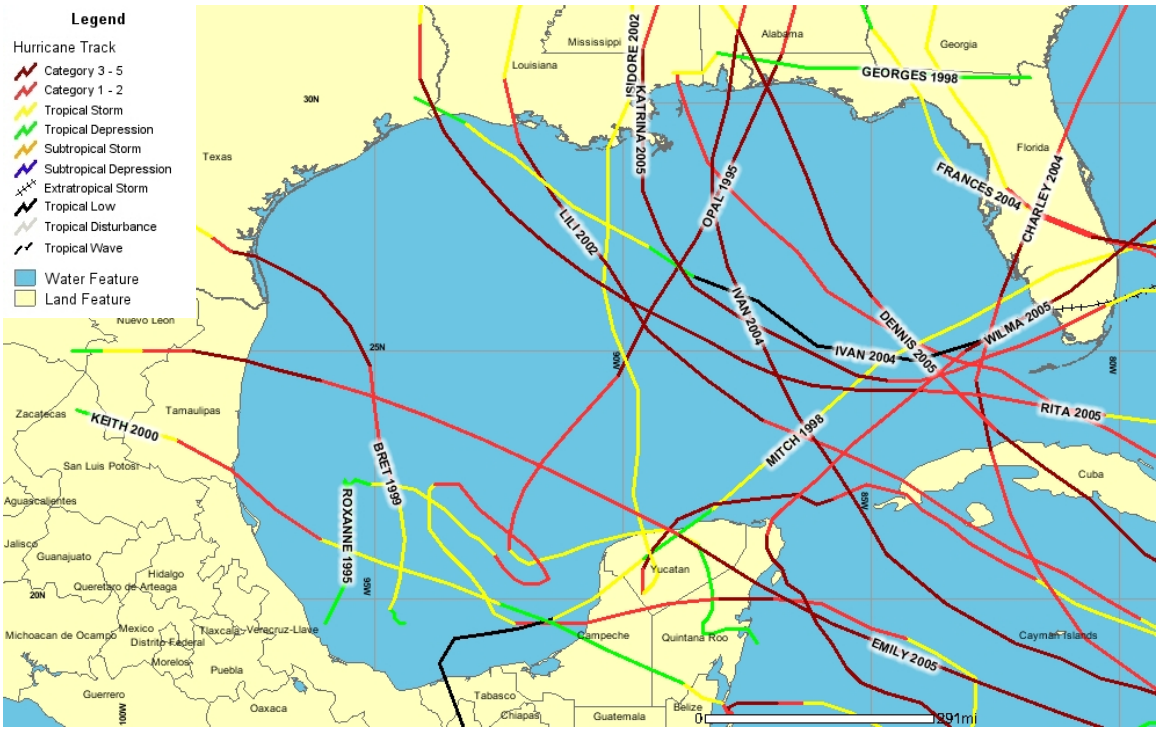


Source: National Oceanic & Atmospheric Administration HURDAT database.

75- percent chance of an above-normal hurricane season. In addition to the multi-decadal cycle, NOAA also points to early indications of a cooling (La Niña) pattern in the equatorial Pacific Ocean as an additional factor in its projection of above-normal activity for the 2007 Atlantic hurricane season.

Atlantic tropical storms and hurricanes that impact the United States usually follow one of three general paths: along the Eastern seaboard, across Florida and striking the Gulf Coast, or through the Caribbean Sea and moving north to strike the Gulf Coast. About one-third of Atlantic storms eventually pass through the Gulf of Mexico. Storm tracks that pass through the Gulf are of particular concern to the energy industry since platforms along the Outer Continental Shelf (OCS) located off the shores of Texas, Louisiana, Mississippi, and Alabama produce a large quantity of crude oil and natural gas. The map in Figure 2 illustrates the tracks of major hurricanes that passed through the Gulf of Mexico during 1995 through 2006 and highlights the intense weather experienced by the OCS over the last decade.

Figure 2. Major Hurricanes in the Gulf of Mexico, 1995-2006



Note: Hurricane Ivan made two passes through the Gulf of Mexico.
Source: National Oceanic & Atmospheric Administration Coastal Services Center

Impacts to Gulf of Mexico Crude Oil and Natural Gas Production

The Gulf of Mexico region is an important source for U.S. crude oil and natural gas production. In 2006, crude oil production from the Federally-administered OCS fields accounted for nearly 27 percent of total U.S. oil production, and marketed production of Gulf OCS natural gas was about 15 percent of the U.S. total. In addition to production from Federal leases, Texas, Louisiana, Alabama, and Mississippi also contribute significant onshore and State-administered offshore production.

Offshore platform operators must evacuate personnel and shut in production temporarily to protect facilities when severe weather threatens. Hurricanes Katrina and Rita passed directly over the OCS producing region, and caused longer-lasting disruptions as a result of damage to production infrastructure. A total of 113 platforms were destroyed and 52 platforms suffered significant

damaged.[2] The vast majority of the destroyed platforms were older platforms that did not meet current design specifications mandated by the Minerals Management Service (MMS). If these destroyed structures are replaced, they will likely be able to better withstand hurricane force winds.

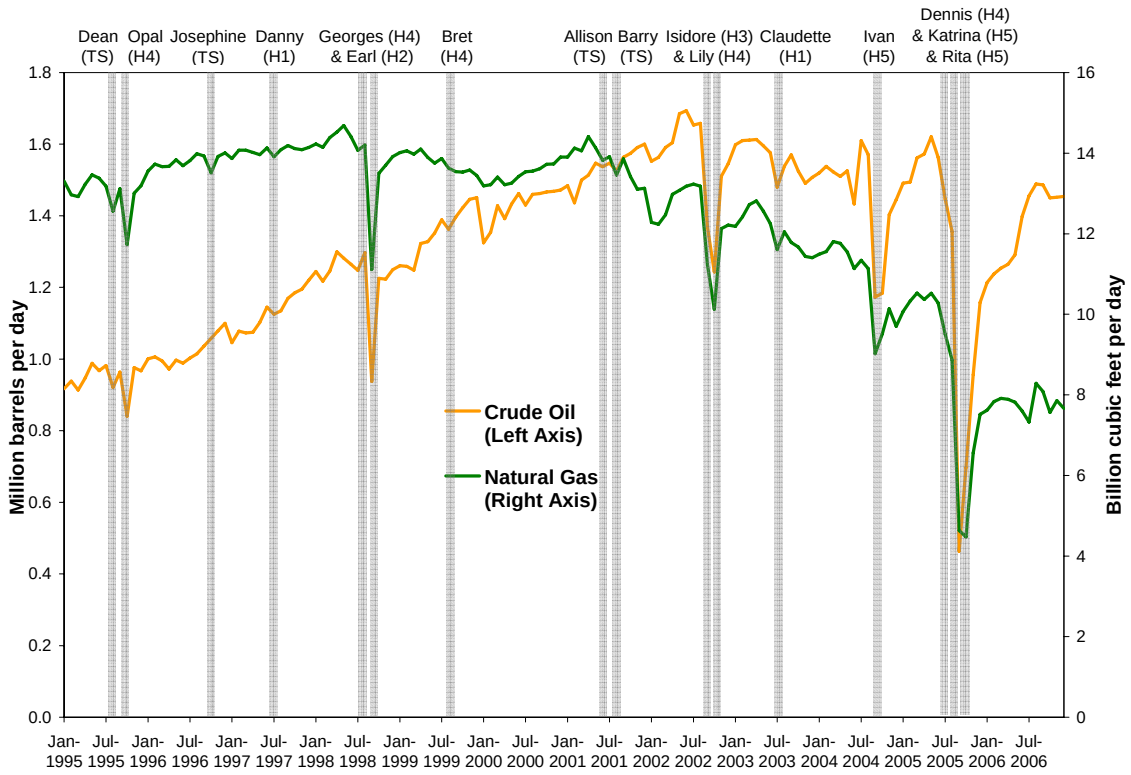
At one point just after the landfall of Rita, 93 percent of Gulf platforms were evacuated. As much as 1.5 million bbl per day of crude oil (100 percent of normal Gulf OCS daily production) and 8.8 bcf per day of natural gas (88 percent of normal daily production) were shut in while the two hurricanes passed over the producing region. The cumulative impacts of Katrina and Rita were just as extraordinary. Through the end of 2005, MMS reported that the cumulative loss as a result of the disruption from those two hurricanes was 109 million bbls of crude oil (about 20 percent of annual Gulf production) and 561 bcf of natural gas (15.3 percent of annual production). MMS continued to collect Katrina and Rita shut-in reports through June 19, 2006.

In addition to the upstream impacts to Gulf production, the 2005 hurricanes had significant impacts on midstream and downstream infrastructure. They damaged 457 underwater pipelines, and the Louisiana Offshore Oil Port had to temporarily stop accepting shipments during both hurricanes. A number of onshore crude oil refineries and natural gas processing facilities also suffered heavy damage. After Katrina struck the Louisiana coast, nearly 2 million bbls per day of refinery capacity was shut down either due to direct damage or interruption of power supplies. A total of more than 4.9 million bbls per day of refinery capacity was shut down after Hurricane Rita hit the Texas coast.

Although Hurricanes Katrina and Rita had effects on Gulf crude oil and natural gas operations that lasted many months, severe weather in the region historically impacts operations only for short periods of time. Figure 3 shows oil and natural gas production in the Gulf OCS for 1995 through 2006 with the effects of various tropical storms and hurricanes highlighted. The disruptions from severe weather often can be identified by temporary dips in production from normal levels. There have been six major hurricanes during the past decade that have caused significant disruption in oil and natural gas production: Opal (1995), Georges (1998), Lili (2002), Ivan (2004) and Katrina and Rita (2005).

[2] Department of Energy, Office of Fossil Energy (2006). Impact of the 2005 Hurricanes on the Natural Gas Industry in the Gulf of Mexico Region. <http://www.fe.doe.gov/programs/oilgas/publications/index.html>

Figure 3. Federal Gulf of Mexico (OCS) Crude Oil and Natural Gas Production, 1995-2006



Note: TS = Tropical Storm. H*n* = Category *n* hurricane.
Source: Energy Information Administration and National Oceanic and Atmospheric Administration.

However, with the exception of Ivan, which shut in an average of about 25 percent of monthly production, and Katrina and Rita, which shut in about 70 percent of monthly production, most disruptions have been temporary with near-normal production returning the following month. In fact, most severe weather systems in the Gulf have shut production in for only a few days. For example, in 1997 Hurricane Danny passed within 50 miles of the center of OCS production, yet it registered a barely perceptible drop in daily production rates, shutting in about 2 percent of that month's oil and natural gas production. Hurricane Bret (1999) with 125 mph winds slightly impacted crude oil production but had almost no effect on the trend in natural gas production.

Shut-in Production Outlook

Seasonal hurricane-related disruptions to crude oil and natural gas production are difficult to forecast, primarily due to the uncertainty involved in predicting intensity of severe weather and the affected locations. Appropriate discussion of production outages in the face of such uncertainty requires an analysis not just of the expected impact, but also the probabilities inherent in certain scenarios. Our projections for shut-in production during the 2007 hurricane season are derived using Monte Carlo simulation techniques. Based on information from the latest NOAA seasonal hurricane outlook and an analysis of the production impact from past tropical storms and hurricanes, we simulate the sampling distributions for seasonal shut-in crude oil and natural gas production. These sampling distributions summarize the expected level of shut-in production, and they also illustrate the uncertainty of the projections by outlining the probabilities of various outage scenarios.

Our Monte Carlo model simulates the number of tropical storms, moderate hurricanes, and intense hurricanes passing through the Gulf of Mexico and the outage caused by each storm. The number of each type of Gulf storm is assumed to follow a Poisson distribution. The mean of each distribution is equal to the average number of each type of storm passing through the Gulf during a typical season and is adjusted based on how NOAA's Atlantic hurricane projection compares to the historical average number of Atlantic hurricanes. From 1950 through 2006, an average of 2.7 intense hurricanes, 3.5 moderate hurricanes and 4.1 tropical storms have occurred within the Atlantic basin each season. The current 2007 *Atlantic Hurricane Season Outlook* predicts 13 – 17 named storms will form within the Atlantic Basin, including 7 to 10 total hurricanes of which 3 to 5 will be intense. Thus, the relevant statistical means of NOAA's Atlantic basin projections are: 4 intense hurricanes, 4.5 moderate hurricanes, and 6.5 tropical storms (a total of 15 named storms) during the upcoming hurricane season.

From 1950 through 2006, the Gulf of Mexico[3] has experienced an average of 0.8 intense hurricanes, 0.9 moderate hurricanes and 1.7 tropical storms each season. Assuming that storm activity in the Gulf will be proportionately higher consistent with the increase in storm activity in the Atlantic, we applied the ratio between NOAA's Atlantic outlook and the historical Atlantic averages to the Gulf averages. The corresponding adjusted means for the Gulf are: 1.2 intense

[3] For this analysis, the Gulf of Mexico is defined as the area within the rectangle bounded by 18° N – 31° N latitude and 81° W – 98° W longitude.

Table 1. Estimated Shut-in Production by Type of Weather System, 1995-2006

	Crude Oil (million barrels)		Natural Gas (billion cubic feet)	
	Mean	Std Dev	Mean	Std Dev
Tropical Storm	541	671	4.12	6.91
Moderate Hurricane [a]	1,360	2,124	9.70	15.70
Intense Hurricane [b]	13,153	19,500	78.55	112.87

[a] Category 1 or 2. [b] Category 3, 4, or 5

Source: Energy Information Administration estimates

hurricanes, 1.2 moderate hurricanes, and 2.7 tropical storms. Our Monte Carlo simulation model assumes that the Poisson distribution means for each type of Gulf storm are equal to these adjusted averages.

The simulated seasonal outage caused by each storm is based on the average estimated cumulative shut-in production caused by tropical storms and hurricanes passing through the Gulf of Mexico from 1995 through 2006. The Minerals Management Service collects shut-in statistics from crude oil and natural gas producers in the Gulf of Mexico, however, these statistics have only been collected for the past few years and not for every tropical storm or hurricane. Prior to 1998, all shut-in information was submitted on a voluntary basis. In order to provide a consistent basis for estimating shut-in production, this report relies on observed patterns in historical crude oil and natural gas production data to approximate historical shut-in values. The methodology for imputing the shut-in values from each weather system that passed through the Gulf of Mexico during 1995 through 2006 is described in Appendix A1. Descriptive statistics for shut-in production caused by each type of weather system are shown in Table 1.

The average outage statistics illustrate how weather-related production impacts increase dramatically with the severity of the storm. The mean outage for intense hurricanes is skewed by the 100 million bbls of crude oil and 600 bcf of natural gas cumulative production shut in by Hurricanes Katrina and Rita during 2005. The wide range of production impacts is also reflected in the large standard deviations. In order to simulate shut-in production for each simulated Gulf tropical storm or hurricane, we assumed that the outages are normally distributed. Any negative simulated shut-in values were assumed to represent zero production impact, possibly because the path of the simulated storm did not threaten any offshore platforms. The total seasonal shut-in production is

Table 2. Simulated Cumulative Shut-in Production for 2007 Hurricane Season

Crude Oil (million barrels)		Natural Gas (billion cubic feet)	
50th Percentile (Median)	13.22	50th Percentile (Median)	86.53
90th Percentile	57.47	90th Percentile	344.25
95th Percentile	72.19	95th Percentile	430.69
Mean	22.95	Mean	140.95
Outage Scenario Probabilities		Outage Scenario Probabilities	
P(No Shut-In)	0.0219	P(No Shut-In)	0.0219
P(> 25 MMbbls Shut-in)	0.3670	P(> 150 Bcf Shut-in)	0.3730
P(> 50 MMbbls Shut-in)	0.1430	P(> 300 Bcf Shut-in)	0.1370
P(> 100 MMbbls Shut-in)	0.0130	P(> 600 Bcf Shut-in)	0.0130

Source: Energy Information Administration Monte Carlo simulation estimates

calculated as the sum of the simulated outages from each simulated tropical storm or hurricane. The sampling distributions for seasonal shut-in crude oil and natural gas production were constructed using 10,000 Monte Carlo simulations of hurricane activity within the Gulf of Mexico.

The sampling distributions, which are conditioned on NOAA's prediction of the number of Atlantic named storms and hurricanes, describe both the expected levels of production outages and the probabilities of various possible shut-in quantities. Table 2 shows various statistics and probabilities that describe the shut-in sampling distributions for the 2007 hurricane season. Complete cumulative probability distribution function charts for both crude oil and natural gas are shown in Appendix A2.

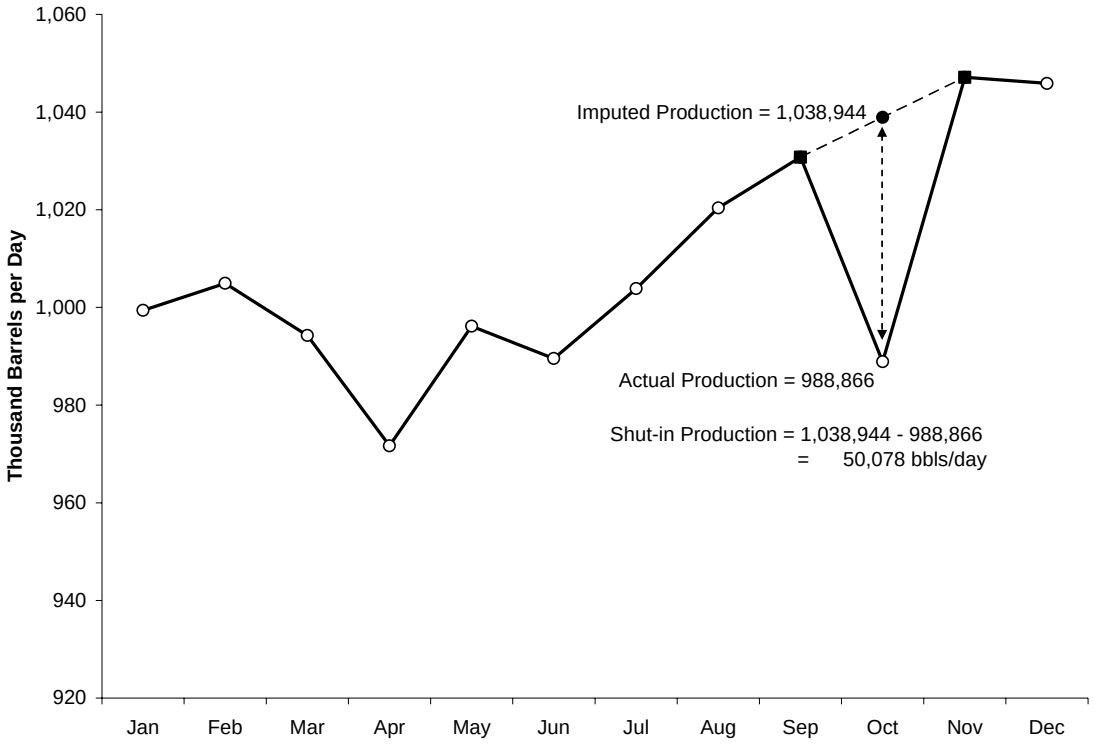
The extreme skewness of the two distributions is evident in the large difference between the mean and median values. For crude oil, the median level of cumulative shut-in production is 13.2 million bbls in constrast to a mean of 23 million bbls. For natural gas, the median shut-in production level is 86.5 bcf in constrast to the mean of 141 bcf. This skewness occurs because our simulation allows for the possibility of another season like 2005. Given that such outcomes represent extreme outliers and the vast majority of simulated outages are comparatively low, the median statistic is a better representation of expected levels of shut-in production. The median value of a sampling distribution indicates an equal probability, 50 percent, of an event's outcome either falling below or exceeding the value.

The sampling distributions derived from the Monte Carlo simulation also allow an analysis of other possible outage scenarios. For example, the percentile statistics indicate a 10-percent probability (90th percentile) of losing more than 57 million bbls of crude oil and 345 bcf of natural gas during the hurricane season. In addition, we can analyze the likelihood of repeating either the destructive 2005 season or the quiet 2006 season. The sampling distributions indicate a 1.3-percent likelihood of a repeat of a hurricane season similar to 2005 with cumulative outages exceeding 100 million bbls of crude oil and 600 bcf of natural gas. On the other hand, there is a 2.2-percent chance that offshore production will be unaffected by hurricanes or tropical storms during 2007 as it was last year. During a season that experiences the average number of Gulf hurricanes, the probability of no shut-in production is approximately 8 percent. Other possible scenarios can be examined using the cumulative probability distribution functions shown in Appendix A2.

Appendix A1. Methodology for Estimating Historical Shut-in Production

The methodology is based on the observation that disruptions caused by tropical weather result in noticeable but temporary decreases from short-term production trends. For those months in which a hurricane or tropical storm passed through the Gulf of Mexico, production in the absence of storm-related disruptions is imputed as the associated monthly value on a trend line connecting production in the month preceding hurricane activity and production in the month of recovery. Shut-in production is then defined as the difference between the imputed production and actual production. If the imputed production value lies below actual production, then shut-in production is assumed to be zero. Figure 4 illustrates this methodology by showing the crude oil production impact of Tropical Storm Josephine in October 1996.

Figure A1. Effect of Tropical Storm Josephine on Gulf Crude Oil Production, 1996



Often, more than one hurricane or tropical storm passes through the Gulf of Mexico during a given month. In such cases, estimated shut-in production was apportioned to each storm using a weight equal to the storm's ACE index

divided by the closest distance to the geographic center of offshore production.[4] A few intense hurricanes had lingering effects over several months; a portion of shut-in production in subsequent months were allocated to these hurricanes. Estimation of shut-in production using this methodology introduces additional uncertainty into the analysis, however the estimated values for recent hurricanes are strongly correlated with reported Minerals Management Service shut-in statistics. Table A1 lists each tropical storm or hurricane that passed through the Gulf of Mexico along with the estimated cumulative shut-in production for the hurricane season.

Table A1. Gulf of Mexico Tropical Storms and Hurricanes and Estimated Shut-in Production, 1995-2006

Name	Date	Maximum Category [a]	ACE Index	Closest Distance [b] (miles)	Estimated Outage Crude Oil (MMbbls)	Estimated Outage Natural Gas (Bcf)
Allison	Jun 1995	1	3.08	358	624	0.33
Dean	Jul 1995	0	0.28	136	189	4.03
Erin	Aug 1995	1	2.59	282	1,529	15.45
Gabrielle	Aug 1995	0	1.40	476	490	4.94
Jerry	Aug 1995	0	0.25	607	67	0.68
Opal	Oct 1995	4	10.81	230	2,951	25.33
Roxanne	Oct 1995	3	15.76	468	2,112	18.13
Dolly	Aug 1996	1	3.70	589	0	0
Josephine	Oct 1996	0	1.61	252	1,455	13.75
Danny	Jul 1997	1	4.63	50	990	6.31
Charley	Aug 1998	0	0.85	263	0	0
Earl	Sep 1998	2	3.70	125	3,765	27.53
Frances	Sep 1998	0	1.64	264	787	5.76
Georges	Sep 1998	2	11.83	195	7,695	56.27
Hermine	Sep 1998	0	0.57	54	1,337	9.77
Mitch	Nov 1998	0	1.36	509	1,482	0.03
Bret	Aug 1999	4	11.12	325	1,722	5.68
Harvey	Sep 1999	0	1.73	325	764	5.18
Irene	Oct 1999	1	3.34	692	281	3.92
Beryl	Aug 2000	0	0.89	438	0	0.90
Gordon	Sep 2000	1	3.35	465	0	0.51
Helene	Sep 2000	0	1.42	280	0	0.36
Keith	Oct 2000	1	2.47	580	421	0

Table continued on next page

[4] Distance is calculated using tropical weather system latitude and longitude measurements from the HURDAT database and the average latitude and longitude of all OCS production platforms.

Table A1. Gulf of Mexico Tropical Storms and Hurricanes and Estimated Shut-in Production, 1995-2006, continued

Name	Date	Maximum Category [a]	ACE Index	Closest Distance [b] (miles)	Estimated Outage Crude Oil (MMbbls)	Estimated Outage Natural Gas (Bcf)
Allison	Jun 2001	0	0.61	214	1,015	7.04
Barry	Aug 2001	0	2.47	291	2,747	13.27
Gabrielle	Sep 2001	0	1.46	493	0	0
Bertha	Aug 2002	0	0.25	134	0	0
Edouard	Sep 2002	0	0.12	652	11	0.07
Fay	Sep 2002	0	1.33	151	493	3.08
Hanna	Sep 2002	0	1.81	163	619	3.87
Isidore	Sep 2002	3	16.30	91	10,095	63.06
Lili	Oct 2002	4	10.80	27	6,075	46.91
Bill	Jul 2003	0	1.39	49	0	4.66
Claudette	Jul 2003	1	6.07	135	2,500	15.90
Erika	Aug 2003	1	1.98	208	226	0
Grace	Aug 2003	0	0.49	209	56	0
Henri	Sep 2003	0	0.53	416	375	2.73
Larry	Oct 2003	0	4.02	556	172	0
Bonnie	Aug 2004	0	2.62	220	748	0
Charley	Aug 2004	4	5.75	608	596	0
Frances	Sep 2004	0	1.64	454	93	0.40
Ivan	Sep 2004	5	26.77	25	27,294	118.09
Jeanne	Sep 2004	1	1.23	517	61	0.26
Matthew	Oct 2004	0	1.01	68	1,362	34.51
Arlene	Jun 2005	0	2.56	270	1,534	5.73
Bret	Jun 2005	0	0.37	657	91	0.34
Cindy	Jul 2005	1	1.52	95	946	6.66
Dennis	Jul 2005	4	8.44	302	1,653	11.64
Emily	Jul 2005	4	13.06	387	1,995	14.05
Gert	Jul 2005	0	0.53	598	52	0.37
Jose	Aug 2005	0	0.45	677	293	1.90
Katrina	Aug 2005	5	17.07	138	54,902	355.77
Rita	Sep 2005	5	22.37	77	48,351	255.59
Stan	Oct 2005	1	2.15	585	9	2.69
Tammy	Oct 2005	0	0.20	621	1	0.24
Wilma	Oct 2005	4	21.92	566	97	28.30
Alberto	Jun 2006	0	2.64	249	0	0

[a] 0 = Tropical storm. 1-5 = Category *n* hurricane

[b] Closest distance that hurricane or tropical storm passed to geographic center of all OCS platforms.

Appendix A2. Sampling Distributions for Cumulative Shut-in Gulf of Mexico Crude Oil and Natural Gas Production During 2007 Hurricane Season

Figure A2. Cumulative Probability Distribution Curve for Shut-in Crude Oil Production

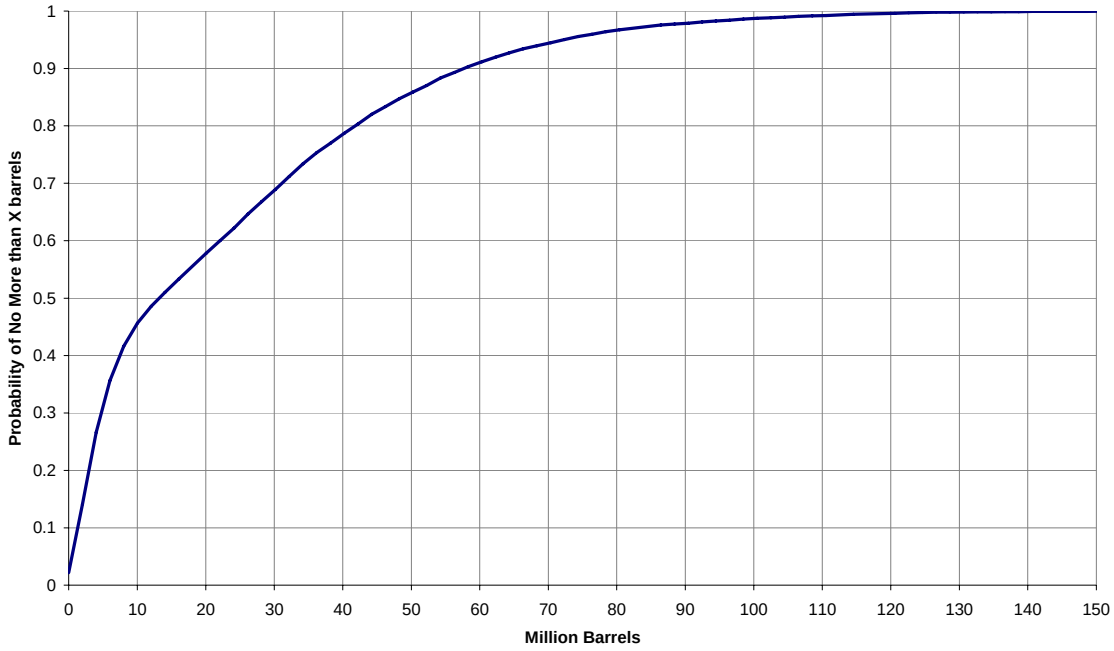


Figure A3. Cumulative Probability Distribution Curve for Shut-In Natural Gas Production