



Summary of 2007 Atlantic Tropical Cyclone Season and Verification of Authors' Seasonal Forecasts

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Summary

The 2007 Atlantic hurricane season was 30% below average in terms of the ACE index but 50% above average in terms of tropical storm numbers. The total ACE index was the lowest since 2002 and the US ACE index was the lowest since 2000. The TSR forecasts, as in 2006, overpredicted activity in general although tropical storm numbers were well predicted. Three factors can cumulatively account for most of the overprediction. First, August-September sea surface temperatures in the hurricane main development region were cooler than expected; second, October was exceptionally quiet for activity; third, very little activity occurred in the subtropics.

The Tropical Storm Risk (TSR) consortium presents a validation of their seasonal deterministic and probabilistic forecasts for North Atlantic hurricane activity in 2007. These forecasts were issued monthly from the 7th December 2006 to the 6th August 2007. They include separate predictions for tropical storms, hurricanes, intense hurricanes and the ACE (Accumulated Cyclone Energy) index, each given for the following regions: North Atlantic basin, tropical North Atlantic, US landfalling and Caribbean Lesser Antilles landfalling. Tropical storm numbers were well predicted but the ACE index was overpredicted. US landfalling activity was also overpredicted.

Features of the 2007 Atlantic Season

- The 2007 Atlantic season saw 15 tropical storms, 6 hurricanes, 2 intense hurricanes and a total ACE index of 70. This ACE index is approximately 30% below the 1950-2006 climate norm, and is the quietest season with respect to the ACE index since 2002.
- Hurricane Humberto made landfall in Texas with 1-minute sustained winds of 80 kts causing approx US\$ 50 million in insured loss. Prior to landfall Humberto intensified from a 25 kt tropical depression to a 80 kt hurricane in 24 hours. Only three other storms (Celia 1970, Arlene 1963 and Flora 1963) have intensified more in 24 hours from below tropical storm strength.
- Two Category 5 hurricanes (Dean and Felix) made landfall on the Yucatan Peninsula. This is the first time that two Category 5 Atlantic hurricanes have made landfall in the same year.



Dean was the first Category 5 Atlantic hurricane to make landfall since Andrew in 1992. Fortunately both storms made landfall in sparsely populated areas. 42 deaths were attributed to Dean and 133 deaths have been reported due to Felix.

- Hurricane Lorenzo made landfall 40 miles south of Tuxpan in Mexico with 1-minute sustained winds of 70 kts. Five fatalities were attributed to the storm. Damage estimates are unknown.
- Hurricane Noel was the deadliest storm of the 2007 season killing at least 150 people, primarily in Hispaniola due to flooding and mudslides. It later affected Maine and eastern Canada as a vigorous extra-tropical cyclone causing further flooding and wind damage.
- Eight storms formed during the month of September. This ties September 2002 for the most named storm formations in September.
- The season was characterised by a large number of weak short lived systems which led to a high tropical storm count but a relatively low ACE index. Seven of the 15 storms had an ACE index of less than 1.
- The season was characterised by a very quiet second half. 77% of the total basin ACE index occurred before the season mid point of 10th September. At this point overall activity was slightly above-norm. The second half of the season saw activity only 31% of norm.

Individual Storm and Loss Summary 2007							
No.	Name	Dates	Peak Wind (kts)	Minimum Pressure (mb)	Hurricane Category	Category at US Landfall	Estimated Insured Loss (US \$ bn)
1	Andrea	9-11 May	50	1001	-	-	-
2	Barry	1-2 Jun	50	997	-	-	-
3	Chantal	31 Jul-1 Aug	45	994	-	-	-
4	Dean	13-23 Aug	145	906	5	-	2
5	Erin	15-19 Aug	35	1003	-	TS	-
6	Felix	31 Aug-5 Sep	145	929	5	-	unknown
7	Gabrielle	8-11 Sep	50	1004	-	TS	-
8	Humberto	12-14 Sep	80	985	1	1	0.05
9	Ingrid	12-17 Sep	40	1004	-	-	-
10	Jerry	23-24 Sep	35	1003	-	-	-
11	Karen	25-29 Sep	65	988	1	-	-
12	Lorenzo	25-28 Sep	70	990	1	-	unknown
13	Melissa	28-30 Sep	35	1005	-	-	-
14	Noel	28 Oct-2 Nov	70	980	1	-	-
15	Olga	11-13 Dec	50	1003	-	-	-

Verification of Forecasts

1. North Atlantic Hurricane Activity

(a) Deterministic Forecasts: North Atlantic Hurricane Activity 2007					
		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
Average Number (\pm SD) (1950-2006)		102 (\pm 61)	2.7 (\pm 1.9)	6.2 (\pm 2.6)	10.3 (\pm 4.0)
Actual Number 2007		70	2	6	15
TSR Forecasts (\pm SD)	6 Aug 2007	138 (\pm 38)	3.5 (\pm 1.3)	7.8 (\pm 1.7)	14.7 (\pm 2.9)
	4 Jul 2007	142 (\pm 46)	3.5 (\pm 1.6)	7.9 (\pm 2.3)	14.7 (\pm 3.4)
	4 Jun 2007	156 (\pm 48)	3.9 (\pm 1.5)	8.6 (\pm 2.4)	15.7 (\pm 3.4)
	3 May 2007	166 (\pm 50)	4.0 (\pm 1.5)	8.9 (\pm 2.6)	16.1 (\pm 3.8)
	3 Apr 2007	173 (\pm 55)	4.2 (\pm 1.7)	9.2 (\pm 2.7)	16.7 (\pm 4.1)
	5 Mar 2007	177 (\pm 56)	4.3 (\pm 1.7)	9.4 (\pm 2.7)	16.7 (\pm 4.3)
	5 Feb 2007	162 (\pm 57)	3.9 (\pm 1.7)	8.7 (\pm 2.9)	15.7 (\pm 4.6)
	3 Jan 2007	152 (\pm 62)	3.7 (\pm 1.8)	8.3 (\pm 3.0)	15.0 (\pm 4.7)
Gray Forecasts	7 Dec 2006	162 (\pm 60)	3.9 (\pm 1.8)	8.5 (\pm 2.8)	15.7 (\pm 4.5)
	3 Aug 2007	150	4	8	15
	31 May 2007	170	5	9	17
	3 Apr 2007	170	5	9	17
NOAA Forecasts	8 Dec 2006	130	3	7	14
	9 Aug 2007	123-175	3-5	7-9	13-16
	22 May 2007	109-184	3-5	7-10	13-17
Met Office Forecast	19 Jun 2007	-	-	-	13 (\pm 3)
WSI Corporation Forecasts	25 Jul 2007	-	3	6	14
	19 Jun 2007	-	4	8	15

(b) Probabilistic Forecasts: North Atlantic ACE Index 2007					
		Tercile Probabilities			RPSS
		below normal	normal	above normal	
Actual 2007		0	100	0	1
Climatology 1950-2006		33.3	33.3	33.3	0
TSR Forecasts	6 Aug 2007	4	24	72	-1.39
	4 Jul 2007	6	22	72	-1.40
	4 Jun 2007	4	16	80	-1.95
	3 May 2007	3	13	84	-2.24
	3 Apr 2007	3	12	85	-2.32
	5 Mar 2007	3	11	86	-2.40
	5 Feb 2007	6	15	79	-1.88
	3 Jan 2007	10	18	72	-1.43
NOAA Forecasts	7 Dec 2006	6	15	79	-1.88
	9 Aug 2007	5	10	85	-2.32
	22 May 2007	5	20	75	-1.59

Tropical storm numbers were well predicted but the other indices were overpredicted. In general the skill of the TSR deterministic forecasts was comparable to the other forecasting agencies. The probabilistic forecasts were not skilful.

What were the main reasons behind North Atlantic hurricane activity in 2007 being overpredicted? Three factors can cumulatively account for most of the overprediction. These are:

1. **August-September sea surface temperatures (SSTs) in the hurricane main development region (MDR) were cooler than expected**, and cooled as the season progressed. If Aug-Sep MDR SSTs had been predicted correctly the forecast would have called for slightly above-norm hurricane activity.
2. **Very low activity in the sub-tropics.** The TSR Atlantic hurricane forecast has no skill for predicting activity in the sub-tropics. Accordingly, a climatology forecast is used. 23% of the basin ACE index historically comes from storms forming in the sub-tropics. In 2007 the sub-tropics contributed just 6% of the total ACE. This factor contributed to a basin ACE overprediction in 2007 of nearly 20%.
3. **Exceptionally quiet October.** The basin ACE index in October 2007 was just 17% of the climatological ACE index for October. Furthermore, when compared to Octobers occurring in La Niña years during warm phases of the Atlantic Multidecadal Oscillation (average ACE index of 39; October 2007 value of 3), the October 2007 value was just 8% of norm. This factor thus contributed to a basin ACE overprediction of ~35% (though some of this would have appeared also in factor 2 above).

The physical reasons for the very low activity in the sub-tropics and for the exceptionally quiet October 2007 activity remain unclear.

2. MDR, Caribbean and Gulf of Mexico Hurricane Activity

(a) Deterministic Forecasts: MDR, Caribbean and Gulf Hurricane Activity 2007					
		ACE Index ($\times 10^4 \text{ kts}^2$)	Intense Hurricanes	Hurricanes	Tropical Storms
Average Number (\pm SD) (1950-2006)		79 (\pm 59)	2.3 (\pm 1.8)	4.3 (\pm 2.5)	7.0 (\pm 3.3)
Actual Number 2007		66	2	6	10
TSR Forecasts (\pm SD)	6 Aug 2007	110 (\pm 45)	3.2 (\pm 1.2)	5.5 (\pm 1.6)	9.8 (\pm 2.3)
	4 Jul 2007	115 (\pm 46)	3.2 (\pm 1.4)	5.6 (\pm 1.8)	9.8 (\pm 2.3)
	4 Jun 2007	129 (\pm 44)	3.6 (\pm 1.3)	6.3 (\pm 1.9)	10.8 (\pm 2.5)
	3 May 2007	139 (\pm 47)	3.7 (\pm 1.3)	6.6 (\pm 2.0)	11.3 (\pm 2.8)
	3 Apr 2007	145 (\pm 53)	3.9 (\pm 1.5)	6.9 (\pm 2.3)	11.9 (\pm 3.3)
	5 Mar 2007	149 (\pm 55)	4.0 (\pm 1.5)	7.1 (\pm 2.4)	11.9 (\pm 3.6)
	5 Feb 2007	135 (\pm 55)	3.6 (\pm 1.5)	6.4 (\pm 2.5)	10.9 (\pm 3.9)
	3 Jan 2007	125 (\pm 60)	3.4 (\pm 1.6)	6.0 (\pm 2.6)	10.2 (\pm 4.0)
	7 Dec 2006	137 (\pm 58)	3.6 (\pm 1.6)	6.5 (\pm 2.6)	10.9 (\pm 3.9)

The Atlantic Main Development Region (MDR) is the region 10°N - 20°N, 20°W - 60°W between the Cape Verde Islands and the Caribbean. A storm is defined as having formed within this region if it reached at least tropical depression status while in the area. Most of the infamous Atlantic basin hurricanes formed within the MDR, Caribbean Sea and Gulf of Mexico.

b) Probabilistic Forecasts

(b) Probabilistic Forecasts: MDR, Caribbean and Gulf ACE Index 2007					
		Tercile Probabilities			RPSS
		below normal	normal	above normal	
Actual 2007		0	100	0	1
Climatology 1950-2006		33.3	33.3	33.3	0
TSR Forecasts	6 Aug 2007	6	28	66	-1.02
	4 Jul 2007	5	25	70	-1.26
	4 Jun 2007	4	16	80	-1.95
	3 May 2007	3	13	84	-2.24
	3 Apr 2007	3	12	85	-2.32
	5 Mar 2007	3	11	86	-2.40
	5 Feb 2007	6	15	79	-1.88
	3 Jan 2007	10	18	72	-1.43
	7 Dec 2006	6	15	79	-1.88

Overall, activity in the MDR, Caribbean and Gulf was close to average in 2007. However, the numbers of hurricanes and tropical storms were somewhat above norm. For tropical storm and hurricane numbers, the TSR forecasts performed well, with the July and August forecasts being correct. However, the number of intense hurricanes and the ACE index were overpredicted by one standard deviation. This overprediction was caused by the short-lived nature of the majority of the tropical storms in 2007. Indeed, 50 out of the 66 ACE units came from the two category 5 hurricanes Dean and Felix. As a result of the large overprediction of the ACE index no probabilistic forecast showed skill.

3. US Landfalling Hurricane Activity

a) Deterministic Forecasts

US Landfalling Hurricane Activity 2007				
		US ACE Index	Hurricanes	Named Tropical Storms
Average Number (\pm SD) (1950-2006)		2.4 (\pm 2.2)	1.5 (\pm 1.3)	3.1 (\pm 2.0)
Actual Number 2007		1.0	1	3
TSR Forecasts (\pm SD)	6 Aug 2007	2.9 (\pm 1.4)	1.7 (\pm 1.2)	3.9 (\pm 1.7)
	4 Jul 2007	3.6 (\pm 1.6)	2.0 (\pm 1.3)	4.3 (\pm 1.9)
	4 Jun 2007	3.9 (\pm 1.6)	2.2 (\pm 1.3)	4.7 (\pm 1.9)
	3 May 2007	4.2 (\pm 1.6)	2.3 (\pm 1.3)	4.8 (\pm 1.9)
	3 Apr 2007	4.4 (\pm 1.6)	2.4 (\pm 1.3)	5.1 (\pm 2.0)
	5 Mar 2007	4.5 (\pm 1.6)	2.4 (\pm 1.4)	5.1 (\pm 2.0)
	5 Feb 2007	4.0 (\pm 1.6)	2.2 (\pm 1.4)	4.7 (\pm 2.0)
	3 Jan 2007	3.8 (\pm 1.9)	2.1 (\pm 1.4)	4.5 (\pm 2.0)
	7 Dec 2006	4.1 (\pm 2.2)	2.2 (\pm 1.7)	4.7 (\pm 2.2)

b) Probabilistic Forecasts

US ACE Index 2007					
		Tercile Probabilities			RPSS
		below normal	normal	above normal	
Actual 2007		100	0	0	1
Climatology 1950-2006		33.3	33.3	33.3	0
TSR Forecasts	6 Aug 2007	9	30	61	-1.15
	4 Jul 2007	7	20	73	-1.51
	4 Jun 2007	4	16	80	-1.80
	3 May 2007	3	13	84	-1.95
	3 Apr 2007	2	11	87	-2.08
	5 Mar 2007	2	10	88	-2.11
	5 Feb 2007	4	15	81	-1.83
	3 Jan 2007	8	18	74	-1.50
	7 Dec 2006	6	15	79	-1.70

As in 2006, 2007 saw average US tropical storm landfalls but below average US hurricane landfalls. The US ACE index was well below average and was the lowest since 2000. All deterministic forecasts overpredicted US landfalling activity and, as a consequence, no probabilistic forecast showed skill.

The steering winds over the North Atlantic which either favour or hinder US hurricane landfalls (Saunders and Lea, 2005) were near-neutral in August-September 2007. Thus the below-norm value for the US ACE index in 2007 likely occurred because of the below-norm number of intense hurricanes which formed at sea in 2007.

4. Lesser Antilles Landfalling Numbers

Lesser Antilles Landfalling Hurricane Activity 2007					
		ACE Index ($\times 10^4 \text{ kts}^2$)	Intense Hurricanes	Hurricanes	Named Tropical Storms
Average Number (\pm SD) (1950-2006)		1.4 (\pm 2.0)	0.2 (\pm 0.5)	0.4 (\pm 0.7)	1.1 (\pm 1.0)
Actual Number 2007		1.4	0	1	1
TSR Forecasts (\pm SD)	6 Aug 2007	1.9 (\pm 2.0)	0.4 (\pm 0.4)	0.6 (\pm 0.6)	1.5 (\pm 0.9)
	4 Jul 2007	2.0 (\pm 2.1)	0.4 (\pm 0.4)	0.6 (\pm 0.6)	1.5 (\pm 1.0)
	4 Jun 2007	2.3 (\pm 2.1)	0.4 (\pm 0.4)	0.7 (\pm 0.6)	1.7 (\pm 1.0)
	3 May 2007	2.4 (\pm 2.2)	0.4 (\pm 0.4)	0.8 (\pm 0.6)	1.7 (\pm 1.1)
	3 Apr 2007	2.6 (\pm 2.3)	0.4 (\pm 0.4)	0.8 (\pm 0.7)	1.8 (\pm 1.1)
	5 Mar 2007	2.6 (\pm 2.4)	0.4 (\pm 0.4)	0.7 (\pm 0.7)	1.8 (\pm 1.1)
	5 Feb 2007	2.4 (\pm 2.4)	0.4 (\pm 0.4)	0.7 (\pm 0.7)	1.7 (\pm 1.1)
	3 Jan 2007	2.2 (\pm 2.4)	0.4 (\pm 0.4)	0.7 (\pm 0.6)	1.6 (\pm 1.1)
	7 Dec 2006	2.4 (\pm 2.3)	0.4 (\pm 0.4)	0.7 (\pm 0.6)	1.7 (\pm 1.1)

Landfalling activity in the Lesser Antilles in 2007 was very close to the 1950-2006 climatology.

The only tropical storm to affect the islands was Dean, which passed between Martinique and St Lucia as an intensifying category 2 hurricane. Dean was the strongest hurricane to affect the Lesser Antilles since hurricane Ivan in 2004. The TSR forecasts overpredicted the ACE index and tropical storm landfalling numbers but were skilful for hurricane landfalls.

Environmental Factors in 2007

1. Contemporaneous Influences

The basic tenet of sound seasonal hurricane forecasting is to forecast the key environmental conditions at the height of the Atlantic hurricane season in August and September. TSR's two predictors are the forecast July-September (JAS) 2007 trade wind speed, u_T , over the Caribbean Sea and tropical North Atlantic, and the forecast August-September (AS) 2007 sea surface temperature in the hurricane main development region. The former influences cyclonic vorticity (the spinning up of storms) in the main hurricane track region, while the latter provides heat and moisture to power incipient storms in the main track region. The specific predictor values and regions are:

1. Jul-Sep Caribbean 925hPa u-winds [7.5°N-17.5°N, 30°W-100°W] (JAS u_T).
2. Aug-Sep SSTs in the Main Development Region [10°N-20°N, 10°W-60°W] (AS MDR SST).

The climatology for JAS u_T is -6.4ms^{-1} (with the -ve sign indicating an easterly wind). When the trade wind speed is lighter than average (+ve u_T anomaly), cyclonic vorticity within and to the immediate north of the u_T region is enhanced. The primary factor controlling anomalies in summer trade wind speed (u_T) is the anomaly in the zonal SST gradient between the east Pacific (ENSO region) and the Caribbean Sea.

2. Predictor Verification

Predictor Verification 2007			
		JAS u_T (ms^{-1})	AS MDR SST ($^{\circ}\text{C}$)
Actual Value 2007 (1977-2006 Anomaly)		0.56	-0.12
TSR Forecasts (\pm SD)	6 Aug 2007	0.51 (\pm 0.43)	0.00 (\pm 0.14)
	4 Jul 2007	0.45 (\pm 0.47)	0.11 (\pm 0.17)
	4 Jun 2007	0.66 (\pm 0.47)	0.13 (\pm 0.22)
	3 May 2007	0.78 (\pm 0.54)	0.20 (\pm 0.24)
	3 Apr 2007	0.91 (\pm 0.64)	0.16 (\pm 0.27)
	5 Mar 2007	0.91 (\pm 0.70)	0.27 (\pm 0.28)
	5 Feb 2007	0.68 (\pm 0.70)	0.27 (\pm 0.28)
	3 Jan 2007	0.53 (\pm 0.74)	0.25 (\pm 0.29)
	7 Dec 2006	0.68 (\pm 0.74)	0.34 (\pm 0.29)

All the TSR forecasts for u_T showed positive skill and anticipated the correct anomaly sign. The early January and August forecasts proved the most skillful. The TSR forecasts for AS MDR SST were all too high and, in general, were not skillful. The August forecast was the most

skilful, forecasting a neutral SST anomaly and was the only forecast correct to within one standard error. MDR SSTs cooled by about 0.1°C between July and August which may have resulted in the overprediction of the AS MDR SST. The overprediction of the AS MDR SST is partly why the Atlantic hurricane activity was overpredicted this year.

Definitions and Verification Data

The verification is made using track data obtained from the US National Hurricane Center (<http://www.nhc.noaa.gov>) and the Unisys Weather (<http://weather.unisys.com>) websites. Position and maximum windspeeds are supplied at 6-hour time intervals. We interpolate these to 1 hour intervals to deduce the landfalling ACE indices.

Rank Probability Skill Score

The probabilistic skill measure employed is the rank probability skill score (*RPSS*) (Epstein 1969; Goddard et al 2003; Wilks, 2006). Computation of *RPSS* begins with the rank probability score (*RPS*) which is defined as:

$$\sum_{m=1}^{N_{cat}} (CP_{Fm} - CP_{Om})^2$$

where $N_{cat} = 3$ for tercile forecasts. The vector CP_{Fm} represents the cumulative probability of the forecast up to category m , and CP_{Om} is the cumulative observed probability up to category m . The probability distribution of the observation is 100% for the category that was observed and is zero for the other two categories. For a perfect forecast $RPS = 0$. The *RPS* is referenced to climatology to give the *RPSS* which is defined as:

$$RPSS = 1 - \frac{RPS_{fcst}}{RPS_{ref}}$$

where RPS_{fcst} is the *RPS* of the forecast and $RPS_{ref} (=RPS_{cl})$ is the *RPS* of the climatology forecast. The maximum *RPSS* is 1; a negative *RPSS* indicates skill worse than climatology.

Total ACE Index = Accumulated Cyclone Energy Index = Sum of the Squares of 6-hourly Maximum Sustained Wind Speeds (in units of knots) for all Systems while they are at least Tropical Storm Strength. ACE Unit = $\times 10^4$ knots².

US ACE Index = Sum of the Squares of hourly Maximum Sustained Wind Speeds (in units of knots) for all Systems while they are at least Tropical Storm Strength and over the USA Mainland (reduced by a factor of 6). ACE Unit = $\times 10^4$ knots².

Lesser Antilles ACE Index = Sum of the Squares of hourly Maximum Sustained Wind Speeds (in units of knots) for all Systems while they are at least Tropical Storm Strength and within the boxed region (10°N-18°N,60°W-63°W) (reduced by a factor of 6). ACE Unit = $\times 10^4$ knots².

Intense Hurricane = 1 minute sustained winds > 95kts (110mph).

Hurricane = 1 minute sustained winds > 63kts (73mph).

Tropical Storm = 1 minute sustained winds > 33kts (38mph).

SD = Standard Deviation.

USA Mainland = Brownsville (Texas) to Maine.

Lesser Antilles = Island Arc from Anguilla to Trinidad inclusive.

Terciles = Data groupings of equal (33.3%) probability corresponding to the upper, middle and lower one-third of values historically (1950-2005).

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Tropical Storm Risk.com (TSR)

Founded in 2000, *Tropical Storm Risk* (TSR) offers a leading resource for forecasting the risk from tropical storms worldwide. The venture provides innovative forecast products to increase risk awareness and to help decision making within the (re)insurance industry, other business sectors, government and society. The TSR consortium is co-sponsored by Benfield, the world's leading independent reinsurance and risk intermediary, Royal & Sun Alliance, the global insurance group, and Crawford & Company, a global claims management solutions company. The TSR scientific grouping brings together climate physicists, meteorologists and statisticians at University College London and the Met Office.

Tropical Storm Risk has won two major insurance industry awards during the past three years. In 2006 TSR was awarded the prestigious Risk Management Award at the British Insurance Awards, and in 2004 won the British Insurance Award for London Market Innovation of the Year.

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