Summary of 2003 Atlantic Tropical Cyclone Season and Verification of Authors' Seasonal Forecasts

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by Drs Adam Lea and Mark Saunders
Benfield Hazard Research Centre, UCL (University College London), UK.

Summary

A year with an above average Atlantic ACE index but with hurricane numbers close to the 10-year average. The TSR forecasts successfully predicted the number of hurricanes, intense hurricanes and US landfalling activity but underestimated the total ACE index. The latter was due to the exceptionally large ACE contributions from the intense and long-lived hurricanes Fabian and Isabel.

The Tropical Storm Risk (TSR) consortium presents a validation of their seasonal forecasts for the North Atlantic basin, tropical North Atlantic, USA landfalling and Caribbean Lesser Antilles landfalling tropical cyclones in 2003. These forecasts were issued monthly from 16th December 2002 to 6th August 2003, and include separate predictions for tropical storms, hurricanes, intense hurricanes and the ACE (Accumulated Cyclone Energy) index. The July forecast performed best successfully predicting the number of hurricanes, intense hurricanes and US landfalling activity. All forecasts underpredicted the total ACE index. This was due to two exceptionally long lived intense hurricanes and to an underestimate of the MDR sea surface temperatures and Caribbean low level winds during the main hurricane season.

Features of the 2003 Atlantic Season

- The 2003 Atlantic season was an active season, with a total ACE index of 167. This is the seventh highest ACE index since 1950. No prior year since 1950 has had such a high total ACE index with only seven hurricanes.

- A large proportion (63%) of the total ACE index came from just two storms. Hurricane Fabian's ACE index was 43 and hurricane Isabel's ACE index was 63. Isabel's ACE index is the second highest since 1950 (after hurricane Donna in 1960) and is comparable to the ACE index for the whole of the 2002 Atlantic hurricane season (66).

- Hurricane Isabel reached category 5 strength on the 11th September and was the first category 5 hurricane in the Atlantic basin since Mitch (1998). Fortunately it weakened to a category 2 before making landfall in North Carolina with estimated winds of 85 knots. Isabel

was responsible for 30 deaths and insured damage estimated at US $1bn.

• Hurricane Fabian hit Bermuda on 5th September with category 3 strength winds resulting in considerable economic damage with estimates ranging from US $300m to 350m. Hurricane Juan caused US $100m in economic damage when it struck Halifax, Nova Scotia, on 29th September with hurricane category 2 strength winds.

• An active early season. Ana became the first tropical cyclone on record to form in the Atlantic basin in April. Four named storms formed by July 17th. Since 1950, the only other years with a fourth named storm by this early in the season were 1959 and 1997.

• The Atlantic main development region was very active (ACE index of 132) but there were no landfalling storms on the Lesser Antilles. There has been no prior year with such an active main development region with no storm strikes on the Lesser Antilles.

• Odette and Peter both formed in December. The last time two Atlantic tropical storms formed in December was 1887.

No.	Name	Dates	Peak Wind (kts)	Minimum Pressure (mb)	Hurricane Category	Category at US Landfall
1	Ana	22-24 April	45	996	-	
2	Bill	29 Jun-1 Jul	50	997	-	TS
3	Claudette	8-16 Jul	70	981	1	1
4	Danny	17-20 Jul	65	1005	1	
5	Erika	14-16 Aug	65	986	1	
6	Fabian	28 Aug-8 Sep	125	939	4	
7	Grace	30-31 Aug	35	1007	-	TS*
8	Henri	5-6 Sep	45	997	-	
9	Isabel	6-19 Sep	140	920	5	2
10	Juan	25-29 Sep	90	970	2	
11	Kate	27 Sep-7 Oct	110	952	3	
12	Larry	2-6 Oct	50	993	-	
13	Mindy	10-12 Oct	40	1002	-	
14	Nicholas	15-23 Oct	60	990	-	
15	Odette	4-7 Dec	55	994	-	
16	Peter	9-10 Dec	60	990	-	

Individual Storm Summary 2003

* Subject to ratification by the US National Hurricane Center.

Verification of Forecasts

1. Atlantic Total Numbers

Atlantic Total Numbers 2003		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (±SD) (1993-2002)		114 (±67)	12.1 (±3.6)	6.9 (±2.9)	3.0 (±1.9)
Average Number (±SD) (1973-2002)		84 (±52)	9.8 (±3.4)	5.7 (±2.4)	2.1 (±1.4)
Actual Number 2003		167	16	7	3
TSR Forecasts (±SD)	6 Aug 2003	108 (±33)	11.7 (±2.2)	6.5 (±1.2)	2.4 (±1.3)
	4 July 2003	122 (±39)	12.7 (±2.5)	7.2 (±1.4)	2.9 (±1.5)
	10 June 2003	115 (±35)	12.2 (±2.2)	6.8 (±1.6)	2.8 (±1.4)
	6 May 2003	118 (±45)	12.4 (±2.7)	7.0 (±2.0)	2.8 (±1.5)
	11 Apr 2003	97 (±58)	11.1 (±2.9)	6.1 (±2.4)	2.4 (±1.8)
	5 Mar 2003	123 (±62)	12.7 (±3.5)	7.1 (±2.7)	2.9 (±1.9)
	5 Feb 2003	133 (±63)	13.3 (±3.3)	7.6 (±2.7)	3.1 (±1.8)
	7 Jan 2003	116 (±65)	12.3 (±3.4)	6.9 (±2.8)	2.7 (±1.8)
	16 Dec 2002	-	12.4 (±3.5)	7.0 (±2.8)	2.8 (±1.8)
Gray Forecasts	2 Oct 2003	-	14	8	2
	3 Sep 2003	-	14	7	3
	6 Aug 2003	-	14	8	3
	30 May 2003	-	14	8	3
	4 Apr 2003	-	12	8	3
	6 Dec 2002	-	12	8	3
NOAA Forecasts	7 Aug 2003	103-146	12-15	7-9	3-4
	19 May 2003	95-155	11-15	6-8	2-4
Meteorological Institute, Cuba Forecasts	1 Aug 2003	-	12	8	-
	2 May 2003	-	10	6	-

The ACE (Accumulated Cyclone Energy) index is defined as the 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 = $x10^4$ knots^2.

The US ACE index is defined as the 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 US mainland (reduced by a factor of 6). ACE Unit = $x10^4$ knots^2.

TSR successfully predicted that tropical storm activity in the Atlantic would be above the long term average at all leads. With the exception of Gray's September forecast, TSR outperformed the other forecasts in predicting hurricane numbers but was slightly worse at predicting tropical storm numbers. Both TSR and NOAA under forecast the ACE index. This was due to the exceptionally long lived intense hurricanes Fabian and Isabel, which together contributed 106 to the ACE index, and to an underforecast of the Atlantic MDR sea surface temperature and

925mb Caribbean trade wind speed. For more details on Gray's forecasts, see http://typhoon.atmos.colostate.edu/forecasts/.

2. MDR, Caribbean and Gulf of Mexico Total Numbers (Tropical North Atlantic)

MDR, Caribbean and Gulf of Mexico Total Numbers 2003					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (±SD) (1993-2002)		97 (±68)	8.8 (±3.6)	5.2 (±2.9)	3.0 (±1.9)
Average Number (±SD) (1973-2002)		63 (±55)	6.5 (±3.6)	3.8 (±2.5)	1.9 (±1.5)
Actual Number 2003		150	11	5	3
TSR Forecasts (±SD)	6 Aug 2003	90 (±38)	8.4 (±1.8)	4.8 (±1.5)	2.4 (±1.3)
	4 July 2003	105 (±41)	9.4 (±1.9)	5.5 (±1.6)	2.9 (±1.5)
	10 June 2003	98 (±35)	8.9 (±1.9)	5.1 (±1.4)	2.8 (±1.4)
	6 May 2003	100 (±45)	9.1 (±2.4)	5.3 (±1.8)	2.8 (±1.5)
	11 Apr 2003	79 (±58)	7.8 (±3.0)	4.4 (±2.4)	2.4 (±1.8)
	5 Mar 2003	106 (±63)	9.4 (±3.4)	5.4 (±2.6)	2.9 (±1.9)
	5 Feb 2003	116 (±64)	10.0 (±3.4)	5.9 (±2.7)	3.1 (±1.8)
	7 Jan 2003	99 (±66)	9.0 (±3.5)	5.2 (±2.7)	2.7 (±1.8)
	16 Dec 2002	-	9.2 (±3.5)	5.3 (±2.7)	3.0 (±1.7)

The Atlantic Main Development Region (MDR) is the region 10^oN - 20^oN, 20^oW - 60^oW 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.

The 2003 season was very active in the MDR, Caribbean Sea and Gulf of Mexico in terms of the ACE index but was near the 10-year average for hurricane numbers. The ACE index was 55% above the 10-year average, although hurricanes Fabian and Isabel alone contributed an ACE index of 106. The TSR forecasts correctly predicted an average number of hurricanes and intense hurricanes from December 2002 onwards, but underpredicted the ACE index. This overprediction is due to the ACE index being exceptionally high for a season with an average numbers of hurricanes.

3. US Landfalling Numbers

US Landfalling Numbers 2003		ACE Index	Named Tropical Storms	Hurricanes
Average Number (±SD) (1993-2002)		2.7 (±1.7)	3.8 (±2.1)	1.2 (±1.2)
Average Number (±SD) (1973-2002)		1.8 (±1.7)	2.8 (±2.0)	1.2 (±1.3)
Actual Number 2003		2.5	4	2
TSR Forecasts (±SD)	6 Aug 2003	2.5 (±1.3)	3.4 (±1.9)	1.5 (±0.9)
	4 Jul 2003	2.9 (±1.2)	3.7 (±1.9)	1.7 (±0.9)
	10 Jun 2003	2.7 (±1.2)	3.6 (±1.9)	1.6 (±0.9)
	6 May 2003	2.8 (±1.3)	3.6 (±1.9)	1.7 (±1.0)
	11 Apr 2003	2.2 (±1.5)	3.2 (±1.9)	1.4 (±1.1)
	5 Mar 2003	2.9 (±1.5)	3.7 (±1.9)	1.7 (±1.1)
	5 Feb 2003	2.8 (±1.7)	3.9 (±1.9)	1.8 (±1.1)
	7 Jan 2003	-	3.6 (±1.9)	1.6 (±1.1)
	16 Dec 2002	-	3.6 (±1.9)	1.7 (±1.1)

Two hurricanes made landfall in the US which was correctly predicted by TSR. The number of tropical storms making landfall (4) was correctly predicted apart from the forecasts issued in April and August. The US landfalling ACE index was predicted perfectly. Landfalling activity overall was close to the 10-year average.

4. Lesser Antilles Landfalling Numbers

Lesser Antilles Landfalling Numbers 2003		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (±SD) (1993-2002)		2.1 (±2.7)	1.5 (±0.9)	0.7 (±0.8)	0.3 (±0.5)
Average Number (±SD) (1973-2002)		1.3 (±2.1)	1.1 (±1.0)	0.4 (±0.6)	0.2 (±0.4)
Actual Number 2003		0	0	0	0
TSR Forecasts (±SD)	6 Aug 2003	1.9 (±2.1)	1.6 (±0.7)	0.7 (±0.6)	0.4 (±0.3)
	4 July 2003	-	1.7 (±0.8)	0.7 (±0.6)	0.4 (±0.4)
	10 June 2003	-	1.6 (±0.8)	0.7 (±0.6)	0.4 (±0.4)
	6 May 2003	-	1.6 (±0.9)	0.7 (±0.7)	0.4 (±0.4)
	11 Apr 2003	-	1.4 (±1.0)	0.6 (±0.7)	0.3 (±0.4)
	5 Mar 2003	-	1.7 (±1.0)	0.7 (±0.8)	0.4 (±0.4)
	5 Feb 2003	-	1.8 (±1.0)	0.8 (±0.8)	0.4 (±0.4)
	7 Jan 2003	-	1.6 (±1.0)	0.7 (±0.8)	0.4 (±0.4)
	16 Dec 2002	-	1.7 (±0.8)	0.7 (±0.7)	0.4 (±0.4)

The Lesser Antilles ACE index is defined as the 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 (10.0^oN-18.5^oN, 60.0^oW-63.0^oW) (reduced by a factor of 6). ACE Unit $= x10^4 knots^2$.

There were no landfalling hurricanes or tropical storms this year which is unprecedented for such an active main development region. Unfortunately this meant that TSR overforecast landfalling activity in the Lesser Antilles. This year is the third consecutive year without a hurricane strike.

Environmental Factors in 2003

1. Contemporaneous Influences

The principle of sound seasonal hurricane prediction work is to forecast the key environmental conditions at the height of the Atlantic hurricane season. We find that the most important contemporaneous factors are:

1. Aug-Sep SSTs in the Main Development Region [10^oN-20^oN, 10^oW-60^oW] (MDR SST).
2. Jul-Sep Caribbean 925hPa U-Winds [7.5^oN-17.5^oN, 40^oW-110^oW] (CAR U).

The first predictor encompasses SSTs where a large proportion of tropical storms develop, so we expect more storms when the SSTs therein are higher. The second predictor is the surface westerly component of windshear, which we find has a stronger influence on tropical storm and hurricane numbers than windshear itself. On average, the July-August-September 925hPa surface winds in this region are $-6.4ms^{-1}$ (i.e. they are easterlies). We find that when these winds are lighter than average (anomalies are positive), conditions become more favourable for tropical storm development.

A number of researchers claim that ENSO is the most important single parameter influencing Atlantic seasonal hurricane variability. ENSO is included in our model as the primary predictor for the strength of the Caribbean 925hPa U-winds, as are Caribbean SSTs.

2. Predictor Verification

Predictor Values 2003			
		MDR SST (C)	CAR U (ms^{-1})
Actual Value 2003 (1973-2002 Anomaly)		0.50	0.79
TSR Forecasts (±SD)	6 Aug 2003	0.26 (±0.11)	0.22 (±0.40)
	4 July 2003	0.15 (±0.14)	0.51 (±0.46)
	10 June 2003	0.05 (±0.17)	0.44 (±0.46)
	6 May 2003	0.08 (±0.24)	0.48 (±0.58)
	11 Apr 2003	0.05 (±0.25)	0.15 (±0.74)
	5 Mar 2003	0.14 (±0.24)	0.53 (±0.83)
	5 Feb 2003	0.19 (±0.25)	0.67 (±0.79)
	7 Jan 2003	0.14 (±0.25)	0.42 (±0.81)
	16 Dec 2002	0.17 (±0.25)	0.45 (±0.80)

TSR forecasts for the Caribbean U wind were accurate to within 1 standard error with the exception of August, which underpredicted the magnitude of the U wind. This was due to a breakdown in persistence of the U wind from July through to August-September. The MDR sea surface temperatures were underpredicted at all leads. The MDR sea surface temperature warmed rapidly from mid August onwards, and was the second highest since 1950. However if we had predicted both predictors perfectly we would have predicted the total ACE index accurately, but overestimated hurricane numbers. Given that both predictors were large and enhancing, it is surprising that there were only seven hurricanes this year.

Definitions

Definitions				
Tropical Cyclone Type	Category	Peak 1-Min Sustained Wind		Minmum Pressure (mb)
		knots	mph	
Tropical Storm	TS	34-63	39-73	-
Hurricane	1	64-82	74-95	>980
Hurricane	2	83-95	96-110	965-980
Hurricane	3	96-113	111-130	945-965
Hurricane	4	114-135	131-155	920-945
Hurricane	5	>135	>155	<920

Our forecast is validated 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 15-minute intervals.

Future Forecasts and Verifications

1. Extended range forecast for the 2004 Atlantic hurricane season will be issued on 5th December 2003.
2. End-of-season summary for the NW Pacific 2003 tropical cyclone season will be issued in early January 2004.

Tropical Storm Risk.com (TSR)

Tropical Storm Risk.com (TSR) is a venture which has developed from the UK government-supported TSUNAMI initiative project on seasonal tropical cyclone prediction. The TSR consortium comprises experts on insurance, risk management and seasonal climate forecasting. The TSR industry expertise is drawn from *Benfield*, the leading independent reinsurance intermediary, *Royal & SunAlliance*, the global insurance group, and from *Crawford & Company*, a global claims management solutions company. The TSR scientific grouping brings together climate physicists, meteorologists and statisticians at *UCL* (University College London) and the *Met Office*. TSR forecasts are available from http://tropicalstormrisk.com.

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