9A.6 HOW WELL FORECAST WERE THE 2004 AND 2005 ATLANTIC AND US HURRICANE SEASONS?

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1. INTRODUCTION

The 2004 and 2005 hurricane seasons with seven intense hurricane landfalls on the U.S. and an estimated total damage bill approaching US$ 200bn rank as the most active and damaging consecutive hurricane years on record. This high activity was due to a combination of warm sea surface temperatures in the tropical North Atlantic, low vertical wind shear and steering currents that favoured storms being steered towards the U.S. rather than recurving at sea.

Currently there are four main organisations that provide seasonal forecasts of Atlantic tropical cyclone activity: TropicalStormRisk (TSR), Prof W Gray, NOAA and the Meteorological Institute, Cuba. How well did the publically available seasonal outlooks anticipate the record-breaking Atlantic and U.S. hurricane activity in 2004 and 2005, and would business have benefited from acting upon the forecasts made? This paper compares the performance of forecasts (deterministic and probabilistic) issued by different centres at different lead times. It also shows why seasonal forecast precision may now be high enough to offer practical benefits.

FORECAST COMPARISON

For North Atlantic hurricane activity, TSR issues monthly updated forecasts from early December through to early August. Prof Gray issues forecasts in early December, early April, the end of May, early August, early September and early October. NOAA and the Meteorological Institute, Cuba issue forecasts in early May and early August. Two of the groups, TSR and NOAA issue probabilistic and deterministic forecasts.

(a) Deterministic forecasts for North Atlantic hurricane activity in 2004.

North Atlantic Hurricane Activity 2004					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (±SD) (1950-2003)		95 (±54)	9.9 (±3.3)	6.0 (±2.3)	2.5 (±1.9)
Actual Number 2004		228	15	9	6
TSR Forecasts (±SD)	4 Aug 2004	145 (±36)	14.0 (±2.4)	7.6 (±1.1)	3.1 (±1.3)
	5 Jul 2004	114 (±36)	12.3 (±2.4)	6.6 (±1.3)	2.6 (±1.4)
	4 Jun 2004	101 (±34)	11.7 (±2.1)	6.1 (±1.5)	2.4 (±1.3)
	11 May 2004	120 (±40)	12.6 (±2.6)	6.8 (±1.8)	2.7 (±1.3)
	6 Apr 2004	128 (±50)	13.1 (±3.2)	7.2 (±2.1)	2.9 (±1.5)
	5 Mar 2004	122 (±53)	12.8 (±3.6)	7.0 (±2.4)	2.8 (±1.5)
	5 Feb 2004	139 (±53)	13.7 (±3.5)	7.6 (±2.4)	3.1 (±1.5)
	6 Jan 2004	132 (±59)	13.3 (±3.9)	7.2 (±2.6)	2.9 (±1.6)
	5 Dec 2003	132 (±59)	13.0 (±4.0)	7.2 (±2.7)	2.9 (±1.6)
Gray Forecasts	6 Aug 2004	-	13	7	3
	28 May 2004	-	14	8	3
	2 Apr 2004	-	14	8	3
	5 Dec 2003	-	13	7	3
NOAA Forecasts	7 Aug 2004	103-146	12-15	7-9	3-4
	19 May 2004	95-155	11-15	6-8	2-4
Meteorological Institute, Cuba Forecasts	1 Aug 2004	-	12	8	-
	2 May 2004	-	10	6	-

(b) Tercile probabilistic forecasts for North Atlantic hurricane activity in 2004. *RPSS* = Rank Probability Skill Score (Goddard et al. 2003).

North Atlantic ACE Index 2004					
		Tercile Probabilities			RPSS
		below normal	normal	above normal	
Actual 2004		0	0	100	1
Climatology 1950-2003		33.3	33.3	33.3	0
TSR Forecasts	4 Aug 2004	1	13	86	0.95
	5 Jul 2004	7	38	55	0.47
	4 Jun 2004	13	46	41	0.13
	11 May 2004	7	32	61	0.61
	6 Apr 2004	9	26	65	0.70
	5 Mar 2004	13	27	60	0.62
	5 Feb 2004	7	21	72	0.81
	6 Jan 2004	12	23	65	0.72
	5 Dec 2003	12	23	65	0.72
NOAA Forecasts	7 Aug 2004	10	45	45	0.23
	19 May 2004	10	40	50	0.37

(c) Deterministic forecasts for U.S. landfalling hurricane activity in 2004.

US Landfalling Hurricane Activity 2004				
		ACE Index	Named Tropical Storms	Hurricanes
Average Number (±SD) (1950-2003)		2.2 (±2.0)	3.0 (±1.9)	1.4 (±1.2)
Actual Number 2004		7.5	8	5
TSR Forecasts (±SD)	4 Aug 2004	3.1 (±1.4)	4.2 (±1.7)	2.0 (±0.9)
	5 Jul 2004	2.6 (±1.3)	3.6 (±1.7)	1.6 (±0.9)
	4 Jun 2004	2.4 (±1.2)	3.4 (±1.7)	1.5 (±0.9)
	11 May 2004	2.8 (±1.2)	3.8 (±1.7)	1.7 (±0.9)
	6 Apr 2004	3.0 (±1.3)	3.9 (±1.7)	1.8 (±1.0)
	5 Mar 2004	2.9 (±1.3)	3.8 (±1.7)	1.7 (±1.0)
	5 Feb 2004	3.3 (±1.3)	4.1 (±1.7)	1.9 (±0.9)
	6 Jan 2004	3.1 (±1.4)	3.9 (±1.9)	1.7 (±1.1)
	5 Dec 2003	3.1 (±1.4)	3.9 (±1.9)	1.7 (±1.1)

(d) Tercile probabilistic forecasts for U.S. landfalling hurricane activity in 2004.

US Landfalling ACE Index 2004					
		Tercile Probabilities			RPSS
		above normal	normal	below normal	
Actual 2004		0	0	100	1
Climatology 1950-2003		33.3	33.3	33.3	0
TSR Forecasts	4 Aug 2004	70	25	5	0.77
	5 Jul 2004	57	34	8	0.54
	4 Jun 2004	49	40	11	0.35
	11 May 2004	63	31	6	0.65
	6 Apr 2004	67	27	6	0.72
	5 Mar 2004	64	30	6	0.67
	5 Feb 2004	75	22	3	0.83
	6 Jan 2004	68	26	6	0.74
	5 Dec 2003	68	26	6	0.74

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(e) As (a) but for 2005.

(a) Deterministic Forecasts: North Atlantic Hurricane Activity 2005					
		ACE Index ($x10^4kts^2$)	Intense Hurricanes	Hurricanes	Named Tropical Storms
Average Number (±SD) (1950-2004)		98 (±57)	2.6 (±1.8)	6.0 (±2.4)	9.9 (±3.3)
Actual Number 2005		243	7	14	27
TSR Forecasts (±SD)	5 Aug 2005	249 (±36)	6.6 (±1.2)	11.4 (±1.5)	22.1 (±2.3)
	7 Jul 2005	190 (±42)	4.1 (±1.5)	8.8 (±1.9)	15.3 (±2.4)
	7 Jun 2005	159 (±42)	3.5 (±1.4)	7.8 (±1.9)	13.8 (±2.2)
	5 May 2005	158 (±44)	3.6 (±1.4)	7.8 (±2.1)	13.9 (±2.6)
	5 Apr 2005	155 (±50)	3.6 (±1.5)	7.8 (±2.1)	13.9 (±2.9)
	7 Mar 2005	156 (±52)	3.6 (±1.6)	7.9 (±2.3)	14.0 (±3.2)
	9 Feb 2005	151 (±53)	3.5 (±1.6)	7.7 (±2.3)	13.6 (±3.3)
	5 Jan 2005	157 (±56)	3.6 (±1.6)	7.8 (±2.4)	13.9 (±3.5)
	10 Dec 2004	145 (±56)	3.4 (±1.6)	7.5 (±2.5)	13.4 (±3.6)
Gray Forecasts	5 Aug 2005	-	6	10	20
	31 May 2005	-	4	8	15
	1 Apr 2005	-	3	7	13
	3 Dec 2004	-	3	6	11
NOAA Forecasts	2 Aug 2005	158-236	5-7	9-11	18-21
	16 May 2005	105-166	3-5	7-9	12-15
Meteorological Institute, Cuba Forecasts	1 Aug 2005	-	-	9	20
	2 May 2005	-	-	7	13

(f) As (b) but for 2005.

(b) Probabilistic Forecasts: North Atlantic Total ACE Index 2005					
		Tercile Probabilities			RPSS
		below	normal	above	
Actual 2005		0	0	100	1
Climatology 1950-2004		33.3	33.3	33.3	0
TSR Forecasts	5 Aug 2005	0	0	100	1
	7 Jul 2005	0	3	97	0.997
	7 Jun 2005	2	12	86	0.948
	5 May 2005	2	13	85	0.940
	5 Apr 2005	4	16	80	0.899
	7 Mar 2005	4	16	80	0.899
	9 Feb 2005	6	18	76	0.860
	5 Jan 2005	6	16	78	0.884
	10 Dec 2004	8	20	72	0.813
NOAA Forecasts	2 Aug 2005	0	2.5	97.5	0.998
	16 May 2005	10	20	70	0.790

(g) As (c) but for 2005.

US Landfalling Hurricane Activity 2005				
		ACE Index ($x10^4kt^2$)	Hurricanes	Named Tropical Storms
Average Number (±SD) (1950-2004)		2.3 (±2.1)	1.5 (±1.3)	3.1 (±2.0)
Actual Number 2005		5.8	4	7
TSR Forecasts (±SD)	5 Aug 2005	4.4 (±1.7)	3.4 (±1.5)	7.4 (±2.3)
	7 Jul 2005	4.3 (±1.9)	2.2 (±1.5)	5.7 (±2.1)
	7 Jun 2005	3.6 (±1.9)	2.0 (±1.6)	4.2 (±2.1)
	5 May 2005	3.6 (±1.8)	2.0 (±1.5)	4.2 (±2.0)
	5 Apr 2005	3.6 (±1.8)	2.0 (±1.6)	4.3 (±2.0)
	7 Mar 2005	3.6 (±1.9)	2.0 (±1.6)	4.3 (±2.1)
	9 Feb 2005	3.5 (±1.9)	2.0 (±1.6)	4.2 (±2.2)
	5 Jan 2005	3.6 (±2.0)	2.0 (±1.7)	4.3 (±1.9)
	10 Dec 2004	3.4 (±2.0)	1.9 (±1.7)	4.1 (±2.2)

(h) As (d) but for 2005.

US Landfalling ACE Index 2005					
		Tercile Probabilities			RPSS
		below	normal	above	
Actual 2005		0	0	100	1
Climatology 1950-2004		33.3	33.3	33.3	0
TSR Forecasts	5 Aug 2005	0	15	85	0.933
	7 Jul 2005	4	14	82	0.920
	7 Jun 2005	9	21	70	0.787
	5 May 2005	8	21	71	0.798
	5 Apr 2005	9	21	70	0.787
	7 Mar 2005	9	20	71	0.802
	9 Feb 2005	11	22	67	0.746
	5 Jan 2005	10	20	70	0.790
	10 Dec 2004	13	22	65	0.718

Table 1 (a-h): Comparison of deterministic and probabilistic forecasts from various forecasting organisations for total Atlantic and U.S. landfalling hurricane activity in 2004 and 2005.

All forecast groups correctly predicted that the 2004 Atlantic hurricane season would be more active than normal but underpredicted the extreme values for overall activity (Table 1(a)). This includes the TSR and Gray extended range forecasts from early December 2003. The TSR early August forecast proved the most skilful prior main-season forecast, while Gray and NOAA provided the best forecasts from May and June. The tercile probabilistic forecasts for total Atlantic activity in 2004 (Table 1(b)) showed excellent skill back as far as early December 2003. All the TSR probabilistic forecasts (except early June) were more skilful than NOAA's May and August probabilistic forecasts.

The U.S. landfall deterministic forecasts (Table 1(c)) were all skilful predicting above average U.S. landfalling activity but the magnitude of the landfalling activity was underpredicted. The August forecast (Saunders and Lea, 2005) proved best overall. The probabilistic forecasts (Table 1(d)) showed excellent skill predicting a high chance of above-average U.S. landfalling activity as far back as December 2003. The February and August forecasts performed best overall.

The 2005 active hurricane season was generally well predicted by all groups, including from early December 2004 by TSR (Table 1(e)). However, the record-breaking extreme values were underpredicted until early August. The TSR August forecast performed best overall, outperforming the other competing forecasts. The TSR December and April forecasts outperformed Gray's December and April forecasts. The tercile probabilistic forecasts for total Atlantic activity (Table 1(f)) again showed excellent skill back to early December 2004 with the August forecast having perfect skill. All the TSR forecasts outperformed NOAA's May forecast. The U.S. landfalling deterministic forecasts (Table 1(g)) performed well with the August forecast correctly predicting the number of tropical storm landfalls. The U.S. landfalling probabilistic forecasts (Table 1(h)) showed excellent skill correctly predicting above-average U.S. landfalling activity as far back as December 2004. The August forecast (Saunders and Lea, 2005) and July forecast performed best overall.

FORECAST BUSINESS APPLICATION

The TSR early August forecast model (Saunders and Lea, 2005) correctly anticipates whether U.S. hurricane losses are above-median or below-median in 74% of years between 1950 and 2003. This skill combined with the success of the seasonal U.S. landfalling hurricane forecasts for 2004 and 2005 (Table 1), suggests that forecast precision may now be high enough to offer potential benefits to a range of U.S. industry whose returns are affected by hurricane damage. One such industry is the insurance industry.

Figure 1 shows the financial benefit to the insurance industry of using the TSR early August forecasts. The diagram displays the probability of a U.S. hurricane season's total insured loss conditional on the TSR forecast. The chance of a large total loss is clearly much higher in years when the forecast is high. For example, a total hurricane insured loss of $10 bn is eight times more likely to occur when the forecast is high compared to when it is low. Clearly if extra reinsurance cover were purchased in the high forecast years a company's volatility in losses (or risk) would be reduced. One measure of volatility is the Expected Shortfall (ES) – the average loss than can be expected every, say, 100 years. For the 1 in 100 year loss ES has values of $20bn (low forecast), $40bn (medium forecast) and $100bn (high forecast).

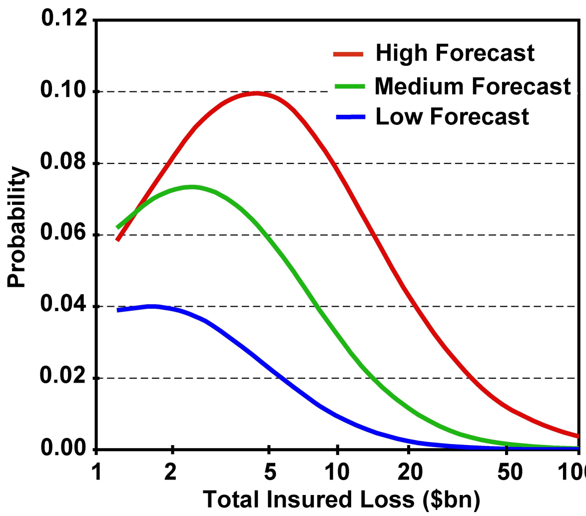

Figure 1: Probability of a given total hurricane insured loss based on the TSR forecasts for high, medium and low U.S. hurricane landfalling activity from 1st August (Saunders and Lea, 2005).

For the damaging 2004 and 2005 hurricane seasons the TSR early August forecasts predicted U.S. landfalling hurricane activity in the upper quartile and upper decile respectively. Thus TSR would have recommended that insurance companies purchase extra protection. By following this forecast guidance individual insurers (and others whose returns are affected by U.S. hurricane damage) could have reduced their losses in 2004 and 2005.

A methodology which allows insurers and reinsurers to use these seasonal hurricane forecasts to better manage their business and, potentially, rethink business decisions, has recently been developed by TSR and the Benfield ReMetrics team (Simmons and Saunders, 2005). This methodology shows how the latest seasonal hurricane forecast:

a) Changes the expected or average level of U.S. hurricane loss for the coming season.
b) Adjusts the expected likelihood of extreme losses for the coming U.S. hurricane season.
c) Provides a better reference for the cost/benefit of adjustments to both outwards and inwards reinsurance.

SUMMARY

The 2004 and 2005 Atlantic and U.S. landfalling hurricane seasons were both predicted to be active (upper tercile activity to high probability) from the previous December. Overall the TSR forecasts slightly outperformed those from the other forecast groups (certainly the case for U.S. landfalling activity).

The recent advances in the seasonal prediction of hurricane activity reaching the coast of the United States combined with the forecast successes of 2004 and 2005 suggest that the precision of seasonal hurricane forecasts is now high enough to be practically useful.

Acknowledgements. We thank David Simmons (Benfield), Alan Fowler (Royal & Sun Alliance) and Jonathan Clark (Crawford & Company) for industrial liaison.

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