July Forecast Update for Atlantic Hurricane Activity in 2016

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Forecast Summary

TSR reduces its pre-season outlook and predicts Atlantic hurricane activity in 2016 will be slightly above the long-term average. Sizeable uncertainties still remain but there is an 84% likelihood that 2016 will be the most active hurricane season since 2012.

The TSR (Tropical Storm Risk) July forecast update anticipates the 2016 Atlantic hurricane season will be slightly above-norm. This is a slight reduction on our pre-season outlook. The forecast spans the full 2016 Atlantic hurricane season, includes hurricane Alex which formed in January 2016, and employs data through to the end of June 2016. The two reasons for the slight decrease in the TSR forecast since the end of May are firstly La Niña is developing more slowly than anticipated. It is now thought La Niña will reach only weak levels by August-September. Second, the earlier trend towards negative North Atlantic Oscillation conditions has stalled with the implication that hurricane main development region waters in August-September will be slightly cooler than thought earlier. Despite the expectation for a slightly above-norm hurricane season in 2016, sources of uncertainty remain including in the forecast strength of La Niña and in how warm the tropical North Atlantic will be in August-September. Furthermore variance exists in the level of hurricane activity possible from the same climate factors.

Atlantic ACE Index and System Numbers in 2016

		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
TSR Forecast	2016	115 (±44)	3 (±1)	8 (±2)	16 (±3)
66yr Climate Norm	1950-2015	101	3	6	11
10yr Climate Norm	2006-2015	94	3	6	14
Forecast Skill at this Lead	1980-2015	49%	28%	43%	38%

Key: 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 = $x10^4$ $knots^2$.
Intense Hurricane = 1 Minute Sustained Wind > 95Kts = Hurricane Category 3 to 5.
Hurricane = 1 Minute Sustained Wind > 63Kts = Hurricane Category 1 to 5.
Tropical Storm = 1 Minute Sustained Winds > 33Kts.
Forecast Skill = Percentage Improvement in Mean Square Error over Running 10-year Prior Climate Norm from Replicated Real Time Forecasts 1980-2015.

There is a 45% probability that the 2016 Atlantic hurricane season ACE index will be above-average (defined as an ACE index value in the upper tercile historically (>118)), a 41% likelihood it will be near-normal (defined as an ACE index value in the middle tercile historically (66 to 118) and a 14% chance it will be below-normal (defined as an ACE index value in the lower tercile historically (<66)). The 66-year period 1950-2015 is used for climatology.

Key: Terciles = Data groupings of equal (33.3%) probability corresponding to the upper, middle and lower one-third of values historically (1950-2015).
Upper Tercile = ACE index value greater than 118.
Middle Tercile = ACE index value between 66 and 118.
Lower Tercile = ACE index value less than 66.

ACE Index & Numbers Forming in the MDR, Caribbean Sea and Gulf of Mexico in 2016

		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
TSR Forecast	2016	98 (±41)	3 (±1)	6 (±2)	11 (±2)
66yr Climate Norm	1950-2015	79	2	4	7
10-yr Climate norm	2006-2015	79	2	5	10
Forecast Skill at this Lead	1980-2015	51%	35%	59%	61%

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

There is a 56% probability that the 2016 Atlantic hurricane season ACE index will be above-average (defined as an ACE index value in the upper tercile historically (>91)), a 35% likelihood it will be near-normal (defined as an ACE index value in the middle tercile historically (42 to 91) and a 9% chance it will be below-normal (defined as an ACE index value in the lower tercile historically (<42)). The 66-year period 1950-2015 is used for climatology.

USA Landfalling ACE Index and Numbers in 2016

		ACE Index	Hurricanes	Tropical Storms
TSR Forecast	2016	2.0	1	3
66yr Climate Norm	1950-2015	2.3	1	3
10yr Climate Norm	2006-2015	1.6	1	2
Forecast Skill at this Lead	1980-2015	5%	8%	8%

Key: ACE Index = Accumulated Cyclone Energy 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 = $x10^4$ $knots^2$.
Strike Category = Maximum 1 Minute Sustained Wind of Storm Directly Striking Land.
USA Mainland = Brownsville (Texas) to Maine

USA landfalling intense hurricanes are not forecast since we have no skill at any lead.

There is a 45% probability that in 2016 the USA landfalling ACE index will be above average (defined as a USA ACE index value in the upper tercile historically (>2.49)), a 27% likelihood it will be near-normal (defined as a USA ACE index value in the middle tercile historically (1.00 to 2.49)) and a 28% chance it will be below-normal (defined as a USA ACE index value in the lower tercile historically (<1.00)). The 66-year period 1950-2015 is used for climatology.

Caribbean Lesser Antilles Landfalling Numbers in 2016

		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
TSR Forecast	2015	1.0	0	1	1
66yr Climate Norm	1950-2015	1.3	0	0	1
10yr Climate Norm	2006-2015	0.8	0	0	1
Forecast Skill at this Lead	1980-2015	24%	8%	19%	7%

Key: ACE Index = Accumulated Cyclone Energy 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 region 10°-18°N, 63°-60°W (reduced by a factor of 6).
ACE Unit = $x10^4$ $knots^2$.
Strike Category = Maximum 1 Minute Sustained Wind of Storm Directly Striking Land.
Lesser Antilles = Island Arc from Anguilla to Trinidad Inclusive.

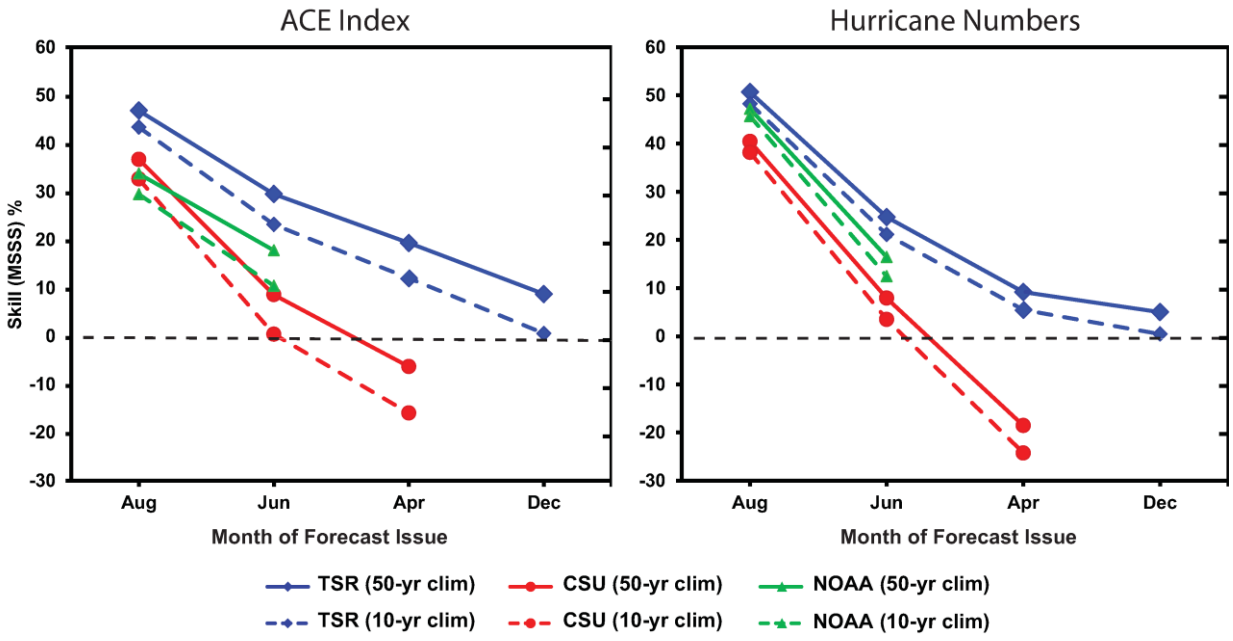
Methodology and Key Predictors for 2016

The TSR statistical seasonal hurricane forecast model divides the North Atlantic into three regions and employs separate forecast models for each region before summing the regional hurricane forecasts to obtain an overall forecast. For two of these three regions (tropical North Atlantic, and the Caribbean Sea and Gulf of Mexico) the forecast model pools different environmental fields involving August-September sea surface temperatures (SSTs) and July-September trade wind speed to select the environmental field or combination of fields which gives the highest replicated real-time skill for hurricane activity over the prior 10-year period. The nature of this process means that the details of the seasonal forecast model can vary subtly from year-to-year and also with lead time within the same year. Separate forecast models are employed to predict the July-September trade wind speed and to predict the August-September SSTs. Finally bias corrections are employed for each predictand based on the forecast model performance for that predictand over the prior 10 years.

The main factors behind the TSR forecast for a slightly above-norm hurricane season in 2016 are the anticipated slight enhancing effect of the July-September forecast trade wind at 925mb height over the Caribbean Sea and tropical North Atlantic region (7.5N – 17.5N, 30W – 100W), and the slight enhancing effect of the August-September forecast sea surface temperature for the Atlantic MDR (10N – 20N, 20W – 60W). The current forecasts for these predictors are 0.81±0.67 ms^{-1} weaker than normal which is slightly stronger than the pre-season forecast of 1.23±0.70 ms^{-1} weaker than normal (1980-2015 climatology), and 0.25±0.19°C warmer than normal which is slightly cooler than the pre-season forecast value of 0.30±0.22°C warmer than normal (1980-2015 climatology). The July-September 2016 trade wind prediction includes the current (16th June 2016) consensus ENSO outlook for August-September 2016 issued by the International Research Institute for Climate and Society at *http://iri.columbia.edu/our-expertise/climate/fore-casts/enso/current*. The forecast skills for these predictors at this lead are 50% and 65% respectively assessed for 1980-2015. However, it should be stressed that sizeable uncertainties in these predictors and in the resultant hurricane forecast still remain. Weaker than normal trade wind speed favours increased vorticity and reduced vertical wind shear where Atlantic hurricanes form. Warmer than normal waters provide more heat and moisture to aid hurricane formation and intensification.

The Precision of Seasonal Hurricane Forecasts

The figure below displays the seasonal forecast skill for North Atlantic hurricane activity for the most recent 13-year period between 2003 and 2015. This assessment uses the seasonal forecast values issued publicly in real-time by the three forecast centres TSR, NOAA (National Oceanic and Atmospheric Administration) and CSU (Colorado State University). Skill is assessed as a function of lead time for two



measures of hurricane activity: ACE and hurricane numbers. Forecast precision is assessed using the Mean Square Skill Score (MSSS) which is the percentage improvement in mean square error over a climatology forecast. Positive skill indicates that the model performs better than climatology, while a negative skill indicates that it performs worse than climatology. Two different climatologies are used: a fixed 50-year (1951-2000) climatology and a running prior 10-year climate norm.

It should be noted that NOAA does not issue seasonal hurricane outlooks before late May and that CSU stopped providing quantitative extended-range hurricane outlooks from the prior December in 2011. It is clear from the figure that there is little skill in forecasting the upcoming number of hurricanes from the previous December. Skill climbs slowly as the hurricane season approaches with moderate-to-good skill levels being achieved from early August. TSR was the best performing statistical seasonal forecast model in predicting ACE and hurricane numbers at all lead times for 2003-2015.

Further Information and Next Forecast

Further information about TSR forecasts and verifications may be obtained from the TSR web site *http://www.tropicalstormrisk.com*. The final TSR forecast update for the 2016 Atlantic hurricane season will be issued on the 5th August 2016.

Appendix – Predictions from Previous Months

1. Atlantic ACE Index and System Numbers*

Atlantic ACE Index and System Numbers 2016					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (1950-2015)		101	11	6	3
Average Number (2006-2015)		94	14	6	3
TSR Forecasts	5 July 2016	115 (±44)	16 (±3)	8 (±2)	3 (±1)
	27 May 2016	130 (±49)	17 (±4)	9 (±3)	4 (±2)
	5 Apr 2016	80 (±57)	12 (±4)	6 (±3)	2 (±2)
	16 Dec 2015	79 (±57)	13 (±5)	5 (±3)	2 (±2)
CSU Forecasts	1 July 2016	95	15	6	2
	1 June 2016	94	14	6	2
	14 April 2016	93	13	6	2
NOAA Forecast	27 May 2016	60-130	10-16	4-8	1-4
UK Met Office	12 May 2016	129	15	9	-

* These numbers include hurricane Alex which formed in January 2016.

2. MDR, Caribbean Sea and Gulf of Mexico ACE Index and Numbers

MDR, Caribbean Sea and Gulf of Mexico ACE Index and Numbers 2016					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (1950-2015)		79	7	4	2
Average Number (2006-2015)		79	10	5	2
TSR Forecasts	5 July 2016	98 (±41)	11 (±2)	6 (±2)	3 (±2)
	27 May 2016	111 (±44)	12 (±3)	7 (±2)	4 (±2)
	5 Apr 2016	65 (±53)	8 (±3)	4 (±2)	2 (±2)

3. US ACE Index and Landfalling Numbers

US Landfalling Numbers 2016				
		ACE Index	Named Tropical Storms	Hurricanes
Average Number (1950-2015)		2.3	3	1
Average Number (2006-2015)		1.6	2	1
TSR Forecasts	5 July 2016	2.0	3	1
	27 May 2016	2.2	3	1
	5 Apr 2016	1.3	2	1

4. Lesser Antilles ACE Index and Landfalling Numbers

Lesser Antilles Landfalling Numbers 2016					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (1950-2015)		1.3	1	0	0
Average Number (2006-2015)		0.8	1	0	0
TSR Forecasts	5 July 2016	1.0	1	1	0
	27 May 2016	1.2	2	1	0
	5 Apr 2016	0.7	1	0	0