July Forecast Update for North Atlantic Hurricane Activity in 2022

Issued: 5th July 2022

by Adam Lea and Nick Wood
EuroTempest Ltd, London, UK

TSR raises its pre-season forecast issued in late May and predicts North Atlantic hurricane activity in 2022 will be 20-25% above the 1991-2020 30-year norm. However, this outlook has uncertainties and the forecast skill at this range is moderate.

Summary: The TSR (Tropical Storm Risk) July forecast update for North Atlantic hurricane activity in 2022 continues to anticipate a season with above-norm activity. Although significant uncertainties remain, we consider that the more likely scenario is for tropical North Atlantic and Caribbean Sea waters to be slightly warmer than normal by August-September 2022, and for weak La Niña conditions to persist through August-September 2022 and into the autumn, contributing to reduced trade winds over the tropical North Atlantic and Caribbean Sea. Both these factors are expected to enhance North Atlantic hurricane activity in 2022. Some Niño 3.4 forecast models predict a slight strengthening of the current La Niña conditions through autumn 2022, which if verified, will increase the chance of enhanced late season activity. An additional factor favouring high activity in 2022 is the unusual early development of a potential tropical cyclone in the Atlantic Main Development Region (MDR) in June.

Contents:

1. TSR July 2022 North Atlantic Seasonal Hurricane Forecasts

1.1 Forecast North Atlantic ACE Index and System Numbers in 2022:

		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
TSR Forecast	2022	150	4	9	18
72-yr Climate Norm	1950-2021	105	2.7	6.4	12.2
30-yr Climate Norm	1991-2020	122	3.2	7.2	14.4
10-yr Climate Norm	2012-2021	125	3.1	7.3	16.8
Forecast Skill at this Lead	2003-2021	23%	30%	23%	25%

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 > 95 kts = Hurricane category 3 to 5.

Hurricane = 1 minute sustained wind > 63 kts = Hurricane category 1 to 5.

Tropical Storm = 1 minute sustained wind > 33 kts.

Forecast Skill = Percentage improvement in mean square error over running 10-year prior climate norm for the TSR publicly-released seasonal outlooks for the 19-years 2003-2021.

The forecast tercile probabilities (1991-2020 data) for the 2022 North Atlantic hurricane season ACE index are as follows: a 46% probability of being upper tercile (>155)), a 46% likelihood of being middle tercile (75 to 155)) and only an 8% chance of being lower tercile (<75)).

Key: Terciles = Data groupings of equal (33.3%) probability corresponding to the upper, middle and lower one-third of values for the current 30-year climate norm (1991-2020). Upper tercile = ACE value greater than 155. Middle tercile = ACE value between 75 and 155. Lower tercile = ACE value less than 75.

1.2 Forecast ACE Index and System Numbers for the North Atlantic Tropics only in 2022:

This forecast refers to tropical storms that form only in the 'North Atlantic tropics' defined as comprising the North Atlantic hurricane main development region (MDR), the Caribbean Sea and the Gulf of Mexico.

		ACE Index	Intense Hurricanes	Hurricanes	Tropical Storms
TSR Forecast	2022	132	4	7	13
72-yr Climate Norm	1950-2021	83	2.4	4.5	7.8
30-yr Climate Norm	1991-2020	97	2.8	5.1	9.4
10-yr Climate Norm	2012-2021	95	2.3	4.9	10.3
Forecast Skill at this Lead	2003-2021	22%	36%	46%	50%

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

Tercile values (1991-2020 climate norm) for the above ACE index are: Upper tercile = 127; lower tercile = 56.

The forecast tercile probabilities (1991-2020 data) for the above ACE index in 2022 are as follows: a 53% probability of being upper tercile (>127), a 39% likelihood of being middle tercile (56 to 127) and only an 8% chance of being lower tercile (<56).

1.3 Forecast US ACE Index and US Landfalling Numbers in 2022:

		US ACE Index	Hurricanes	Tropical Storms
TSR Forecast	2022	3.2	2	4
72-yr Climate Norm	1950-2021	2.5	1.5	3.3
30-yr Climate Norm	1991-2020	2.7	1.6	3.8
10-yr Climate Norm	2012-2021	3.3	1.9	4.4
Forecast Skill at this Lead	2003-2021	0%	11%	19%

Key: US 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.

Tercile values (1991-2020 climate norm) for the US ACE index are: Upper tercile = 3.41; lower tercile = 1.18.

The forecast tercile probabilities (1991-2020 data) for the US ACE index in 2022 are as follows: a 47% probability of being upper tercile (>3.41), a 38% likelihood of being middle tercile (1.18 to 3.41) and a 15% chance of being lower tercile (<1.18).

1.4 Forecast Probability of Exceedance Plots for the North Atlantic Hurricane Season in 2022:

Seasonal outlooks for North Atlantic hurricane activity contribute to the anticipation of risk for insurance companies, other weather-sensitive businesses, and local and national governments. However, the uncertainty associated with such forecasts is often unclear. This reduces their benefit and contributes to the perception of forecast 'busts'. The robust assessment of risk requires a full and clear probabilistic quantification of forecast uncertainty with the forecast issued in terms of probability of exceedance (PoE). In this way the chance of each hurricane number/activity outcome occurring is clear for the benefit of users. Going forward TSR will be including robust forecast probability of exceedance (PoE) information based on the recommendation and methodology described in Saunders et al. (2020).

Figure 1 displays our pre-season forecast PoE plots for the 2022 North Atlantic hurricane season. The forecast PoE curves are computed using the method described in section 3 of Saunders et al. (2020) while the climatology PoE curves are computed directly from observations. The two forecast PoE plots specify the current chance that a given ACE index and/or hurricane total will be reached in 2022 and how these chances differ to climatology.

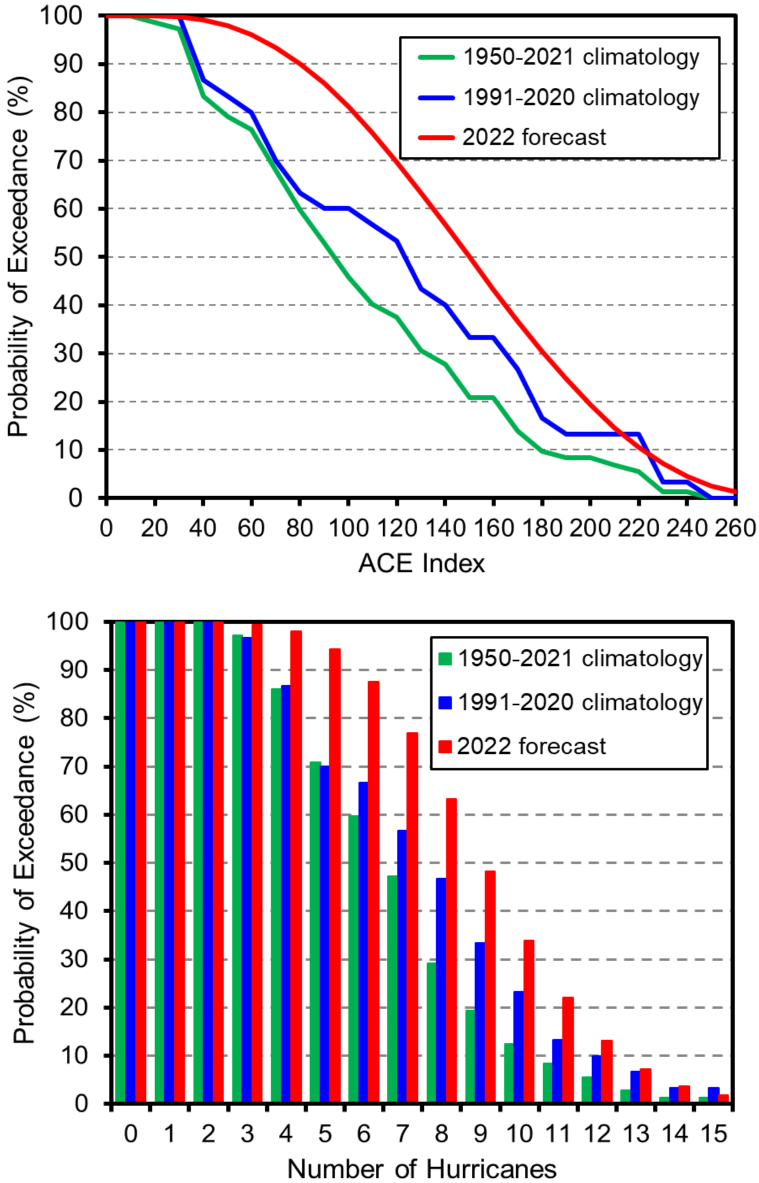

Figure 1. Forecast probability of exceedance (PoE) plots for the North Atlantic ACE index in 2022 (upper panel) and for the number of North Atlantic hurricanes in 2022 (lower panel). Each plot displays three sets of PoE data comprising the TSR forecast PoE curve issued in early July and two climatology PoE curves.

2. TSR Forecast Methodology

2.1 Primary Model:

The TSR forecast models are statistical in nature and are underpinned by predictors that have sound physical links to contemporaneous TC activity. The TSR primary model first divides the North Atlantic basin into three regions: (1) the tropical North Atlantic; (2) the Caribbean Sea and Gulf of Mexico; and (3) the 'rest' region which comprises the North Atlantic area outside regions (1) and (2). The TSR primary model then employs separate forecast models for each of the three regions before summing the regional hurricane forecasts to obtain an overall North Atlantic hurricane forecast.

The two main predictors used by the TSR primary model in making its seasonal North Atlantic hurricane forecasts are:

Predictor 1: The forecast speed of the trade winds for July-August-September for the region 7.5-17.5°N, 100-30°W. The trade winds blow westward across the tropical Atlantic and Caribbean Sea and influence cyclonic vorticity and vertical wind shear over the main hurricane track region.

Predictor 2: The forecast sea surface temperature (SST) for August-September for the region 10-20°N, 60-20°W between west Africa and the Caribbean where many TCs develop during August and September. Waters here provide heat and moisture to help power the development of storms within the hurricane main development region.

Predictor 1 is forecast from the forecast SST anomalies for August-September ENSO (El Niño Southern Oscillation) and August-September Atlantic/Caribbean SSTs for the regions 5°S - 5°N, 90°W - 160°E, and 7.5°N - 17.5°N, 40°W - 85°W respectively. ENSO SSTs are predicted by the statistical consolidated CLIPER model (Lloyd-Hughes, Saunders and Rockett, 2004). Tropical Atlantic/Caribbean SSTs are forecast using a statistical principal component model which, at each forecast lead, employs the 1-month lagged principal component of the leading mode of north Atlantic SST variability for the region 0°N-50°N, 0°W-100°W (Pacific Ocean excluded).

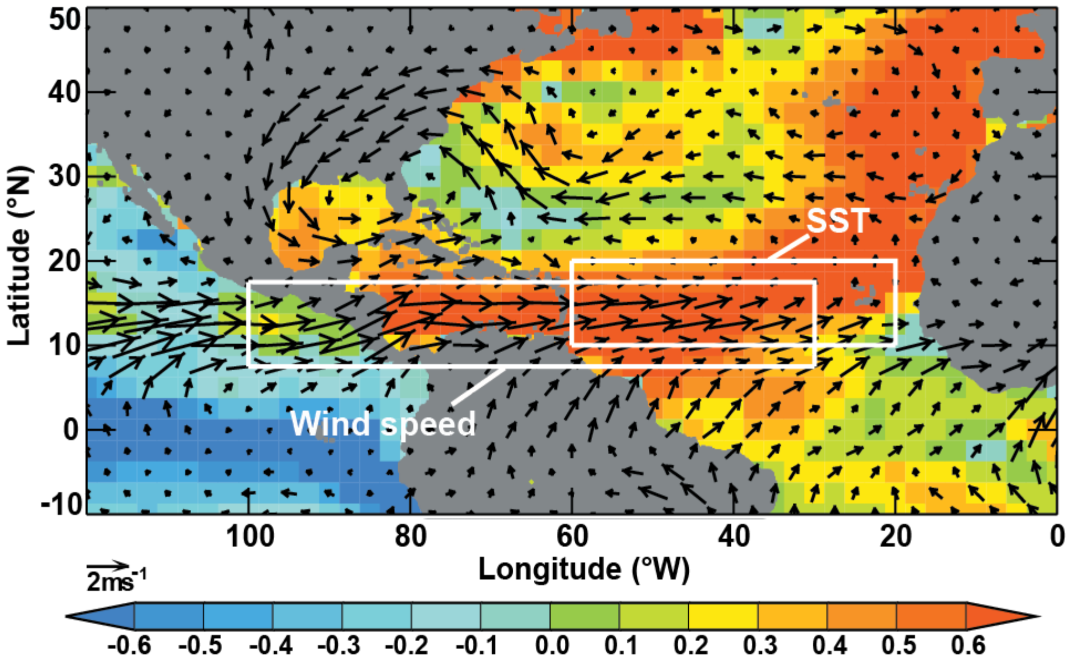

Figure 2. Nature of the TSR statistical model for replicating North Atlantic seasonal hurricane activity. The figure displays the two August-September environmental field areas that the TSR model employs most often in producing a seasonal hurricane outlook. The figure also displays the anomalies in August-September SST (colour coded in °C) and 925 hPa wind (arrowed) linked to active Atlantic hurricane years. Figure taken from Saunders and Lea (2008).

The nature of the TSR primary model is shown in Figure 2 and is described further in Lea and Saunders (2004, 2006), Saunders (2006) and Saunders and Lea (2008). The basis for the trade wind speed being the environmental field that best replicates long-term hurricane activity for the period 1878-2012 is given in Saunders et al. (2017). The methodology of the TSR primary seasonal forecast models is also documented in the recent reviews on seasonal tropical cyclone forecasting by Klotzbach et al. (2017, 2019).

TSR forecasts for US landfalling TC activity issued between December and July employ a historical thinning factor between 'tropical' North Atlantic activity and US landfalling activity. The TSR forecast for US landfalling activity issued in early August employs the persistence of July steering winds (Saunders and Lea, 2005). These winds either favour or hinder evolving hurricanes from reaching US shores during August and September. The replicated real-time correlation skill for predicting the US ACE Index from early August assessed for the 39-year period 1980-2018 is $r = 0.53$.

All regressions are performed using normalized data for all variables (predictands and predictors). This ensures that the requirements of linear regression modeling are met; namely that observations are drawn from normal distributions and that regression errors are normally distributed with a mean of zero. In each case the transform distribution is determined using 1950-2019 data. Table S2 in Supporting Information in Saunders et al (2020) lists some of the statistical distributions used to transform particular data sets to a normalized distribution. Normality is assessed using the Anderson-Darling statistical test.

2.2 Procedures, Checks and Adjustments to Finalise Forecast:

Each TSR seasonal hurricane forecast is initiated by running the TSR primary seasonal forecast model with NCEP/NCAR reanalysis data updated to within a few days of the seasonal forecast issue date. The output from this primary model is then assessed in combination with several other sources of information before the final values for the seasonal forecast are decided. These other sources of information often lead either to the TSR primary forecast model bring rerun with different values for its two main predictors or to the outputs of the primary models being manually adjusted.

The sources of other information that are referred to when finalising the TSR North Atlantic seasonal hurricane forecasts include the following:

- ENSO consensus forecasts compiled and provided by IRI (International Research Institute for Climate and Society).
- NCEP CFSv2 seasonal forecast data (updated daily).
- ECMWF seasonal forecast data (updated monthly).
- NOAA 'ENSO: recent evolution, current status and predictions' weekly report.
- UCL unpublished 'statistical composite prediction of ENSO outcomes' data.
- Tropical Tidbits data and forecast data (updated daily).
- North Atlantic Oscillation (NAO) CPC forecast data and monthly index data (updated twice daily).
- Atlantic Multidecadal Oscillation (AMO) index data (updated monthly).
- Atlantic Meridional Mode (AMM) SST index data (updated monthly).
- UCL unpublished data showing the strength, significance and timing of NAO, ENSO, AMO and AMM seasonal links to upcoming North Atlantic hurricane activity.

The following procedures and adjustments to the outputs from the TSR primary forecast model are made in order to enhance forecast precision:

a) The additional information sources are used to give consensus values for the TSR two underpinning primary predictor values (Aug-Sep Nino 3.4 SST and Aug-Sep MDR SST). In determining the consensus value for each predictor more weight is given to forecasts from the *NCEP CFSv2* and *ECMWF* models and from the *UCL "Statistical composite prediction of ENSO outcomes"*.

b) If the consensus values obtained from (a) for either primary predictor (§2.1) differ by more than 0.1°C from the values output by the TSR primary forecast model then the TSR primary model is rerun with the consensus values for each SST predictor to give a revised seasonal hurricane forecast.

c) If $ENSO_{AMJ}$ is neutral and either NAO_{AMJ} or AMO_{AMJ} is anticipated to lie in either the upper or lower quartile of historical values then a separate regression forecast for North Atlantic hurricane activity is made using either NAO_{AMJ} or AMO_{AMJ} as the sole predictor. This forecast is then used in parallel with the primary model forecast (or the latter is adjusted based on the former).

d) If either AMM_{JJA} or AMM_{JAS} is anticipated to be in the upper or lower quartile then allowance is made for this when finalizing the North Atlantic seasonal hurricane forecast.

e) If forecasts anticipate the intensification of either a La Niña or an El Niño event during the second half of the hurricane season (namely during the period from mid-September to the end of November) the TSR seasonal hurricane forecasts (especially the early July and early August forecasts) are adjusted slightly to reflect this ENSO intensification.

f) If early (pre-August) development of a potential tropical cyclone or tropical cyclone in the Atlantic Main Development Region occurs, the forecast is revised upward.

3. Factors Influencing the July 2022 TSR Forecasts

The reason why the TSR July forecast update for North Atlantic hurricane activity in 2022 calls for ACE-activity 20-25% above the 1991-2020 30-year climate norm is because the two predictors that are used by the TSR primary model (§2.1) are both anticipated to enhance hurricane activity in 2022. These predictors are the July-September forecast trade wind at 925mb height over the Caribbean Sea and tropical North Atlantic (region 7.5°N–17.5°N, 30°W–100°W), and the August-September forecast SST for the tropical North Atlantic (region 10°N–20°N, 20°W–60°W). The current forecast for the July-September trade wind is for 0.77±0.80 ms^{-1} weaker than normal (1991-2020 climatology). The current forecast for the August-September SST is for 0.25±0.33°C warmer than normal (1991-2020 climatology). Weaker than normal trade winds during July-September in the tropical north Atlantic are associated with more cyclonic vorticity and decreased vertical wind shear over the hurricane main development region. This in turn increases hurricane frequency and intensity. Slightly warmer than normal waters provide additional heat and moisture to help power the development of more storms within the hurricane main development region.

The forecasts for the two predictors given above are consensus values obtained by assessing the additional information sources listed in §2.2 and then rerunning the TSR primary model with the consensus values for the two underpinning SST primary predictor values. The latter values were -0.6°C anomaly (1991-2020 climatology) for August-September Nino 3.4 SST, and 0.25°C anomaly (1991-2020 climatology) for August-September MDR SST. The UCL unpublished 'statistical composite prediction of ENSO outcomes' data shows that in 12 out of the 18 years 1950-2021 when a La Niña is present in April-May-June, the same La Niña will persist through to August-September-October. We expect this to happen again in 2022.

In June 2022 a potential tropical cyclone formed in the Atlantic Main Development Region (MDR) which developed into tropical storm Bonnie in the west Caribbean Sea in early July. Since 1950, only five other years have had storms form in the Caribbean during July, with all but one classed as hyperactive seasons.

Historically the skill from the July forecasts for North Atlantic hurricane activity is moderate (§1.1 and Figure 3) due to significant uncertainties in the two August-September predictor fields at this 1-2 month lead. This uncertainty arises due to the uncertainty in the August-September ENSO value and the uncertainty in the sea surface temperature anomalies in the MDR and Caribbean Sea. In addition, even if the two August-September predictor fields are anticipated correctly a spread in hurricane activity levels can still ensue.

4. Precision of TSR Seasonal Hurricane Forecasts 2003-2021 Issued Publicly

The skill of the TSR seasonal forecasts for North Atlantic hurricane activity issued publicly in real-time for the period 2003-2014 were assessed and compared to the skill of the seasonal forecasts issued by Colorado State University and the National Oceanic and Atmospheric Administration by Klotzbach et al (2017) (see their Figures 19.10 and 19.11). This assessment was extended to the 16-year period 2003-2018 by Klotzbach et al (2019) (see their Figure 1). Figure 3 further extends these skill assessments to span the 19-year period between 2003 and 2021. Skill is displayed as a function of forecast lead-time for two measures of seasonal hurricane activity – the basin ACE index and basin hurricane numbers.

Figure 3 shows that the seasonal forecast skill from the prior December is low. However, the skill climbs after April and reaches moderate-to-good levels by early August. Although there are mostly only small differences in forecast skill between the three forecast centres, the TSR model has been either the near-equal best or the best performing statistical seasonal forecast model at all lead times for the period 2003-2021.

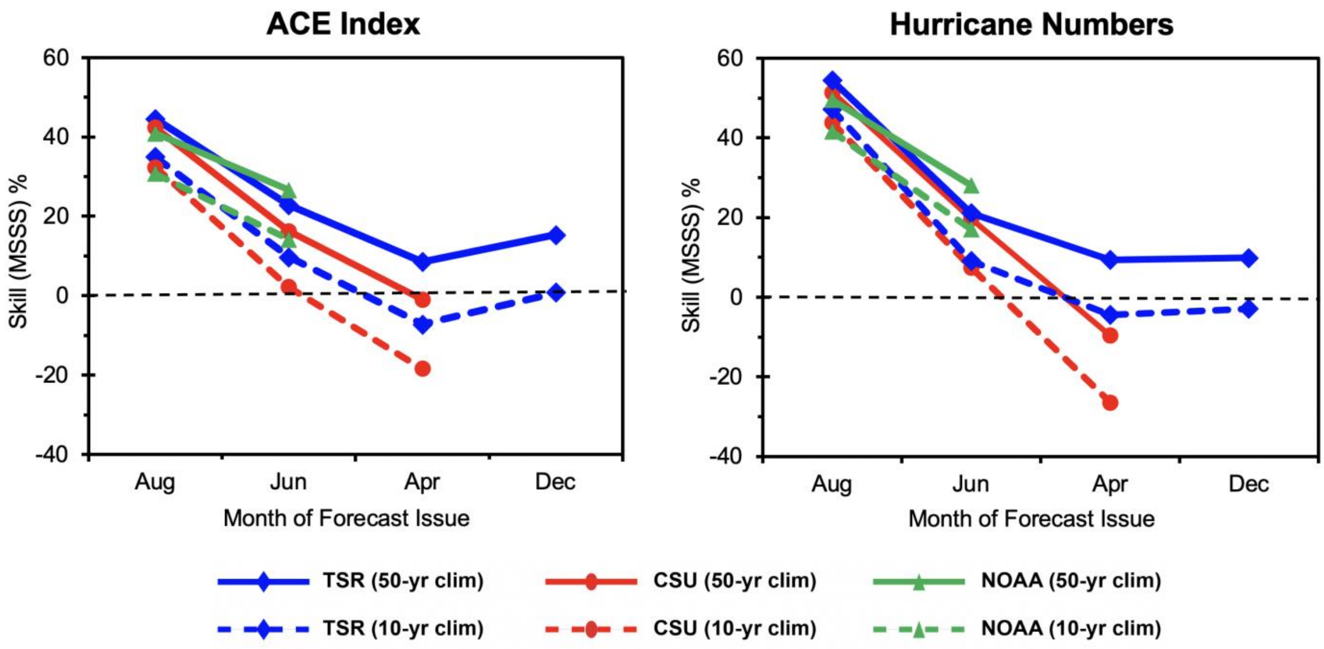

Figure 3. Real-time skill of North Atlantic seasonal tropical cyclone outlooks assessed for the 19-year period 2003-2021. The skill of the seasonal outlooks issued publicly by Tropical Storm Risk (TSR, blue lines), Colorado State University (CSU, red lines), and the National Oceanic and Atmospheric Administration (NOAA, green lines) are compared for ACE (left panel) and for hurricane numbers (right panel). The skill is shown as the Mean Square Skill Score (MSSS) based on a fixed 50-year (1951-2000) climatology and on a running prior 10-year climate norm.

5. Forecast Archive, Next Forecast, Acknowledgements and References

5.1 Forecast Archive and Date of Next Forecast:

The archive of all the TSR publicly released North Atlantic seasonal hurricane forecasts (from 1998 to 2022) may be viewed at *https://www.tropicalstormrisk.com/for_hurr.html*. The final TSR forecast update for the 2022 North Atlantic hurricane season will be issued on Tuesday 9th August, 2022.

5.2 Acknowledgements:

The TSR (Tropical Storm Risk) North Atlantic seasonal hurricane forecasts were instigated in 1998 by Professor Mark Saunders at UCL with funding from the UK insurance industry. Saunders led these

predictions until his retirement in April 2022. Notable contributions to the development and operation of the TSR seasonal hurricane forecasts were made also by the following scientists (all former UCL research assistants of Saunders): Professor Chris Merchant, Dr Paul Rockett, Dr Adam Lea and Frank Roberts.

5.3. References:

Lea, A. S., and Saunders, M. A. (2004). Seasonal predictability of Accumulated Cyclone Energy in the North Atlantic, Proceedings of the 26th Conference on Hurricanes and Tropical Meteorology, Miami, USA, May 3-7, 2004, pp. 419-420.

Lea, A. S., and Saunders, M. A. (2006). How well forecast were the 2004 and 2005 Atlantic and US hurricane seasons? *Weather*, **61,** 245-249.

Klotzbach, P., et al. (2019). Seasonal tropical cyclone forecasting. *Tropical Cyclone Research and Review*, *8*, 134-149. .

Klotzbach, P. J., Saunders, M. A., Bell, G. D., and Blake, E. S. (2017). North Atlantic seasonal hurricane prediction: underlying science and an evaluation of statistical models, in *Climate Extremes: Patterns and Mechanisms*, *Geophysical Monograph Series*, vol 226, edited by S- Y. Wang et al., pp. 315-328, American Geophysical Union, John Wiley & Sons. https://doi.org/10.1002/9781119068020.ch19

Lloyd-Hughes, B., Saunders, M. A., and Rockett, P. (2004). A consolidated CLIPER model for improved August-September ENSO prediction skill. *Wea Forecasting,* **19,** 1089-1105. https://doi.org/10.1175/813.1

Saunders, M. A., and Lea, A. S. (2005). Seasonal prediction of hurricane activity reaching the coast of the United States. *Nature*, **434,** 1005-1008. https://doi.org/10.1038/nature03454

Saunders, M. A. (2006) Winds of change. Post Magazine Risk Report, 28-29, 9 November 2006. Located online at http://tropicalstormrisk.com/docs/Hurricanes-Post09112006.pdf

Saunders, M. A., and Lea, A. S. (2008). Large contribution of sea surface warming to recent increase in Atlantic hurricane activity. *Nature,* **451,** 557-560. https://doi.org/10.1038/nature06422

Saunders, M. A., Klotzbach, P. J., and Lea, A. S. R. (2017). Replicating annual North Atlantic hurricane activity 1878-2012 from environmental variables. *Journal of Geophysical Research-Atmospheres*, **122**(12), 6284-6297. https://doi.org/10.1002/2017JD026492

Saunders, M. A., Klotzbach, P. J., Lea, A. S. R., Schreck, C. J., and Bell, M. M. (2020). Quantifying the probability and causes of the surprisingly active 2018 North Atlantic hurricane season. *Earth and Space Science*, **7**, e2019EA000852. https://doi.org/10.1029/2019EA000852

Appendix: List of Predictions Issued for the 2022 North Atlantic Hurricane Season

1. Atlantic ACE Index and System Numbers:

Atlantic ACE Index and System Numbers 2022						
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (1950-2021)		105	12.2	6.4	2.7
Average Number (1991-2020)		122	14.4	7.2	3.2
Average Number (2012-2021)		125	16.8	7.3	3.1
TSR Forecasts	5 July 2022	150	18	9	4
	31 May 2022	140	18	8	4
	6 April 2022	138	18	8	4
	10 December 2021	122	18	8	3
CSU Forecasts	2 June 2022	180	20	10	5
	7 April 2022	160	19	9	4
NOAA	24 May 2022	109-190	14-21	6-10	3-6
UK Met Office	23 May 2022	176	18	9	4

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

MDR, Caribbean Sea and Gulf of Mexico ACE Index and Numbers 2022					
		ACE Index	Named Tropical Storms	Hurricanes	Intense Hurricanes
Average Number (1950-2021)		83	7.8	4.5	2.4
Average Number (1991-2020)		97	9.4	5.1	2.8
Average Number (2012-2021)		95	10.3	4.9	2.3
TSR Forecasts	5 July 2022	132	13	7	4
	31 May 2022	124	11	6	3
	6 April 2022	117	11	6	3

3. US ACE Index and US Landfalling Numbers:

US Landfalling Numbers 2022				
		ACE Index	Named Tropical Storms	Hurricanes
Average Number (1950-2021)		2.5	3.3	1.5
Average Number (1991-2020)		2.7	3.8	1.6
Average Number (2012-2021)		3.3	4.4	1.9
TSR Forecasts	5 July 2022	3.2	4	2
	31 May 2022	2.8	4	2
	6 April 2022	2.8	4	2