August Forecast Update for North Atlantic Hurricane Activity in 2022

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TSR lowers its forecast issued in early July and now predicts North Atlantic hurricane activity in 2022 will be slightly above the 1991-2020 30-year norm. However, this outlook has significant uncertainties and the forecast skill at this range is moderate.

Summary: The TSR (Tropical Storm Risk) August forecast update for North Atlantic hurricane activity in 2022 lowers its July forecast and anticipates a season with activity close to the 1991-2020 climate norm. 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 moderate La Niña conditions to persist through August-September-October 2022, contributing to reduced vertical wind shear over the tropical North Atlantic and Caribbean Sea. Both these factors are expected to enhance North Atlantic hurricane activity in 2022. La Nina conditions through autumn tend to enhance late season activity though this is not guaranteed. An additional factor favouring above-average activity in 2022 is the unusual early development of a potential tropical cyclone in the Atlantic Main Development Region (MDR) in June. It should be noted that uncertainty is higher than normal at this lead time due to the presence of contradictory climate signals (Section 3). The tropical Atlantic and Caribbean trade winds have been stronger than normal through July, and if this persists through August and September, it will act to reduce hurricane activity through increased vertical wind shear and cooling of tropical Atlantic sea surface temperatures. The August forecast has been reduced on this basis.

Contents:

1. TSR August 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	130	3	8	17
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	34%	45%	47%	64%

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 33% probability of being upper tercile (>155)), a 54% likelihood of being middle tercile (75 to 155)) and only a 13% 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	110	3	6	11
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	25%	49%	58%	77%

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 39% probability of being upper tercile (>127), a 47% likelihood of being middle tercile (56 to 127) and only a 14% 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	35%	45%	51%

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 39% probability of being upper tercile (>3.41), a 42% likelihood of being middle tercile (1.18 to 3.41) and a 19% 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.

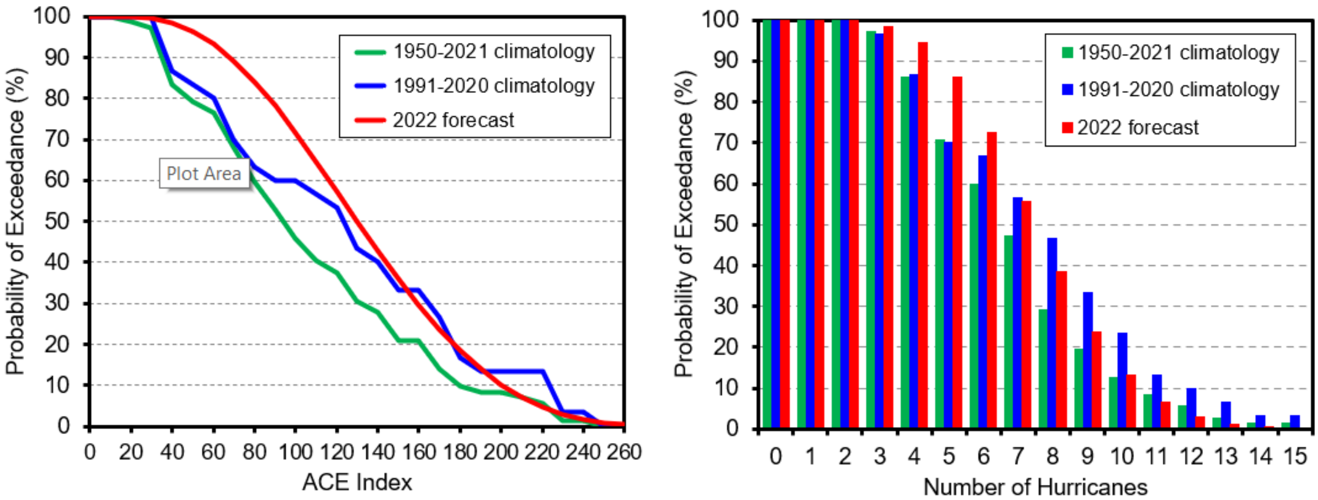

Figure 1. Forecast probability of exceedance (PoE) plots for the North Atlantic ACE index in 2022 (left panel) and for the number of North Atlantic hurricanes in 2022 (right panel). Each plot displays three sets of PoE data comprising the TSR forecast PoE curve issued in early August and two climatology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

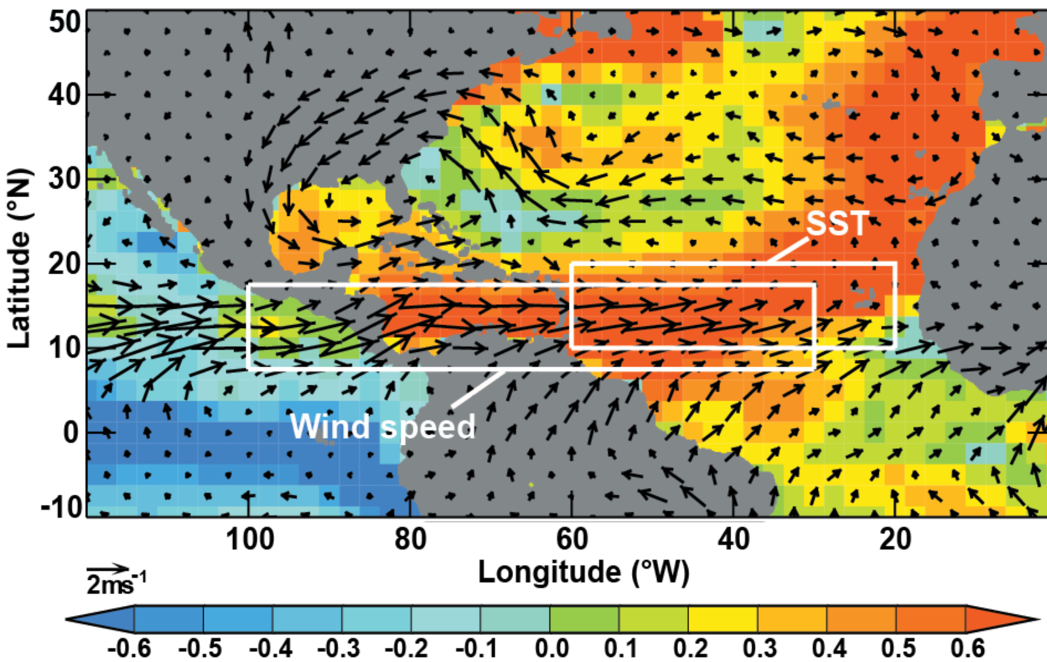

Figure 2. Nature of the TSR statistical model for replicating North Atlantic seasonal hurricane activity. The figure displays the two August-September environmental field areas that the TSR model employs most often in producing a seasonal hurricane outlook. The figure also displays the anomalies in August-September 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 modelling 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 August 2022 TSR Forecasts

The reason why the TSR August forecast update for North Atlantic hurricane activity in 2022 has been lowered and calls for ACE-activity slightly above the 1991-2020 30-year climate norm is because of a combination of factors which, individually, are expected to enhance or suppress north Atlantic hurricane activity.

The first (enhancing) factor is the expected warmer than average August-September tropical Atlantic (region 10°N–20°N, 20°W–60°W) and Caribbean (region 7.5°N–17.5°N, 85°W–40°W) sea surface temperatures. The current forecast for the August-September SST is for 0.25±0.33°C and 0.3±0.31°C warmer than normal respectively (1991-2020 climatology). Warmer than average sea surface temperatures in these regions provide additional heat and moisture to help power the development of more storms within the hurricane main development region and Caribbean Sea.

The second (enhancing) factor is the expected continuation of moderate La Niña conditions through August to November. The forecast for August-September Niño 3.4 SST is -0.73°C anomaly (1991-2020 climatology). La Niña conditions are associated with reduced vertical wind shear across the Caribbean and hurricane main development region and can enhance late season activity in the Caribbean and Gulf of Mexico, although this is not guaranteed. For example, in 2020, the August-October Niño 3.4 SST was -0.79°C and October-November activity was extremely active with five major hurricanes forming, more than twice the number recorded during this period in any previous season. On the other hand, in 2007, the August-October Niño 3.4 SST was -0.93°C and only one tropical depression, one tropical storm and one category 1 hurricane formed after 1st October.

The third (enhancing) factor is the formation of a potential tropical cyclone in the Atlantic Main Development Region (MDR) in June 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 season classed as hyperactive.

The fourth (suppressing) factor is the observed July trade wind speed anomaly over the region 7.5°N–17.5°N, 30°W–100°W which is currently 0.36 ms^{-1} stronger than normal (1991-2020 climatology). Stronger than normal trade winds are linked to higher vertical wind shear over the Caribbean and tropical Atlantic and reduced cyclonic vorticity over the Atlantic main development region, all of which reduce hurricane frequency and intensity. Using data from 1950 to 2021, there is a strong correlation between July trade wind anomaly and August-September trade wind anomaly (Pearson correlation = 0.77), and of the five years where the July Niño 3.4 SST was within 0.1°C of the July 2022 value of -0.61°C and the July trade wind anomaly was negative, three years experienced below average hurricane activity and the mean ACE index over those five years is 96.

Historically the skill from the August forecasts for North Atlantic hurricane activity is moderate to good (§1.1 and Figure 3) due to uncertainties in the two August-September predictor fields at this lead and the strength of La Niña. Additional uncertainty is present this year due to the presence of conflicting parameters described above.

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.

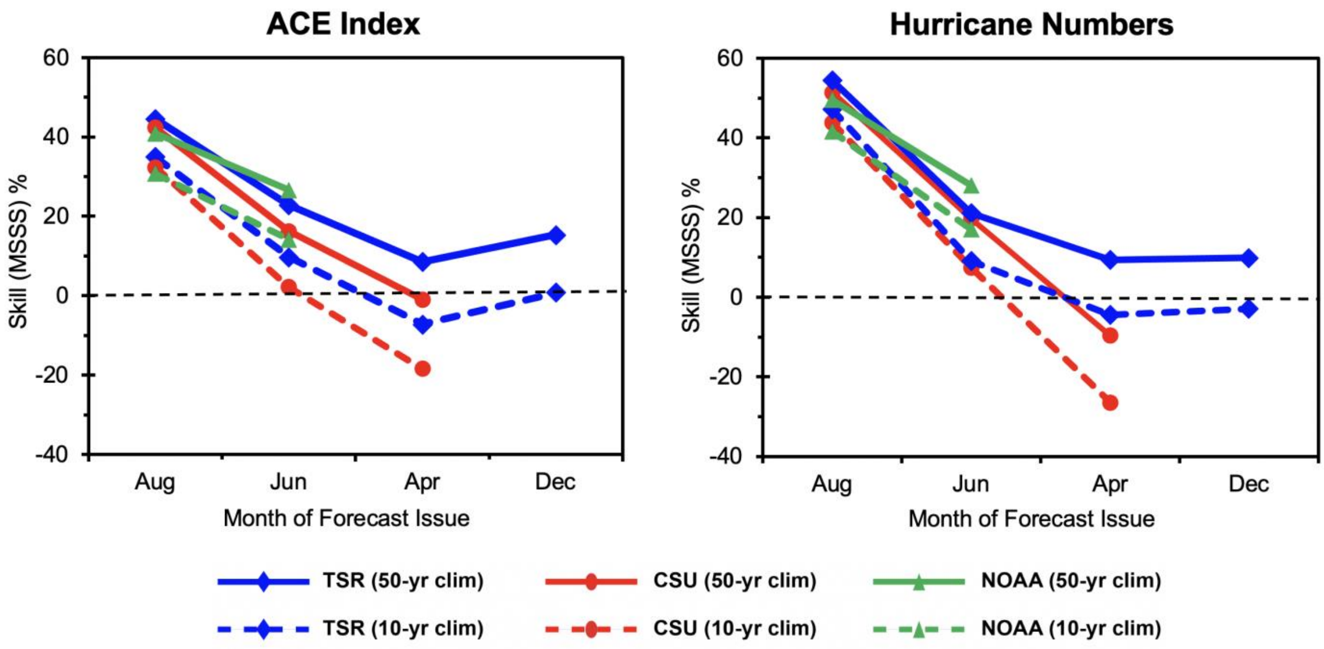

Figure 3. Real-time skill of North Atlantic seasonal tropical cyclone outlooks assessed for the 19-year period 2003-2021. The skill of the seasonal outlooks issued publicly by Tropical Storm Risk (TSR, blue lines), Colorado State University (CSU, red lines), and the National Oceanic and Atmospheric Administration (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*. This is the final TSR forecast for the 2022 North Atlantic hurricane season. A review of the 2022 north Atlantic hurricane season and the seasonal forecasts will be issued in early January 2023.

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:

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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	9 August 2022	130	17	8	3
	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	4 August 2022	150	18	8	4
	2 June 2022	180	20	10	5
	7 April 2022	160	19	9	4
NOAA	4 August 2022	105-181	14-20	6-10	3-5
	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	4 August 2022	110	11	6	3
	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	4 August 2022	3.2	4	2
	5 July 2022	3.2	4	2
	31 May 2022	2.8	4	2
	6 April 2022	2.8	4	2