# Pre-Season Forecast for North Atlantic Hurricane Activity in 2021

## Issued: 27th May 2021

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## Forecast Summary

**TSR slightly raises its April forecast and predicts North Atlantic hurricane activity in 2021 will be 30-35% above the long-term norm. However, this outlook has sizeable uncertainties and the skill of publicly-released hurricane outlooks issued in late May 2003-2020 is low.**

The TSR (Tropical Storm Risk) pre-season forecast update for North Atlantic hurricane activity in 2021 anticipates a season with activity that is ~30-35% above the long-term norm and slightly above the 2011-2020 10-year norm level. The forecast spans the period from 1st June to 30th November 2021 and employs data through to the 22nd May 2021. TSR slightly raises its April forecast due to updated climate signals that point to environmental fields in August-September 2021 being slightly more favourable for Atlantic hurricane activity than thought previously. This updated information comprises the April-May-June 2021 North Atlantic Oscillation being moderately negative which should lead to warming of tropical North Atlantic waters, and to the El Niño Southern Oscillation in August-September-October anticipated to be slightly negative which should contribute to reduced trade winds over the tropical North Atlantic and Caribbean Sea. Both of these environmental fields should enhance North Atlantic hurricane activity in 2021. The forecast has sizeable uncertainties but we consider there is a 59% probability that the North Atlantic hurricane season ACE index in 2021 will be above-average (defined as a value in the upper tercile historically).

## North Atlantic ACE Index and System Numbers in 2021

|  |  | ACE Index | Intense Hurricanes | Hurricanes | Tropical Storms |
|---|---|---|---|---|---|
| TSR Forecast (±FE) | 2021 | 140 | 4 | 9 | 18 |
| 71-yr Climate Norm (±SD) | 1950-2020 | 105 | 3 | 6 | 12 |
| 10-yr Climate Norm | 2011-2020 | 123 | 3 | 7 | 17 |
| Forecast Skill at this Lead | 2003-2020 | 9% | 11% | 11% | 11% |

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 18-years 2003-2020.

There is a 59% probability that the 2021 North Atlantic hurricane season ACE index will be above-average (defined as an ACE index value in the upper tercile historically (>126)), a 28% likelihood it will be near-normal (defined as an ACE index value in the middle tercile historically (74 to 126)) and a 13% chance it will be below-normal (defined as an ACE index value in the lower tercile historically (<74)).

Key:  Terciles = Data groupings of equal (33.3%) probability corresponding to the upper, middle and lower one-third of values historically (1950-2020). Upper Tercile = ACE value greater than 126. Middle Tercile = ACE value between 74 and 126. Lower Tercile = ACE value less than 74.

# Forecast Probability of Exceedance Plots for the 2021 North Atlantic Hurricane Season

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).

The plots below display our extended range outlooks for ACE (upper panel) and for the number of hurricanes (lower panel) in terms of PoE. Each plot displays two sets of PoE data comprising the forecast PoE curve and the 1950-2020 climatology PoE curve. 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 2021 and how these chances differ to climatology.
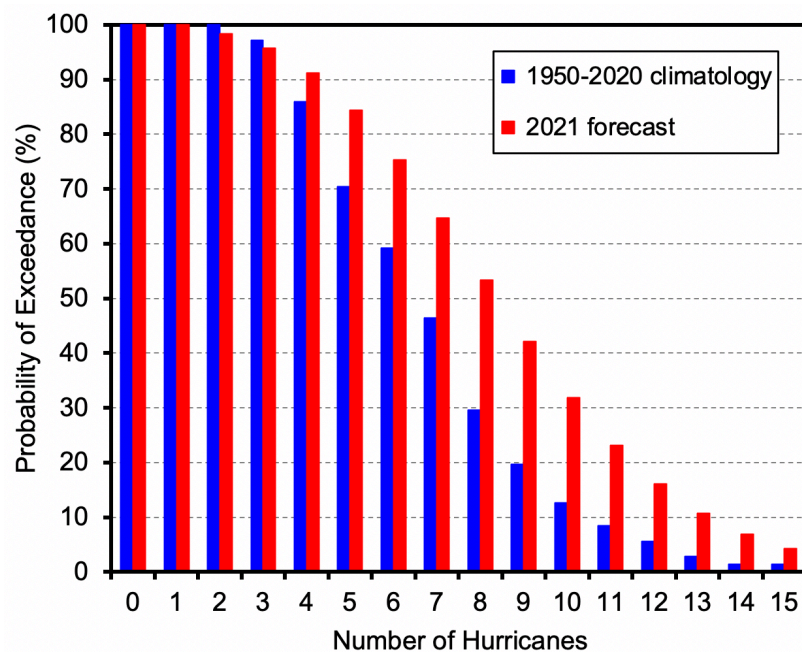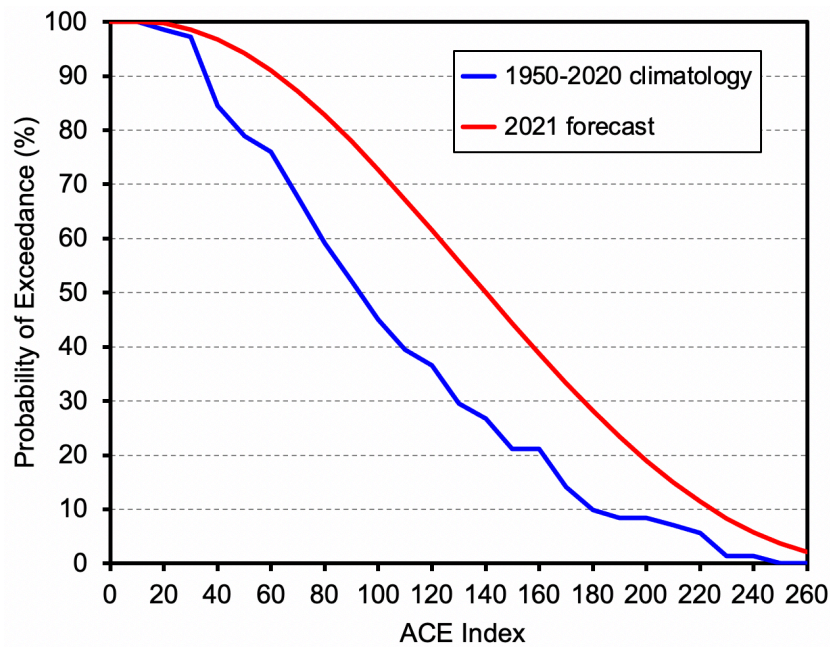
There is a 42% likelihood that the 2021 Atlantic hurricane season will be a 'hyperactive' season defined as an ACE ≥ 165% of the median ACE for 1981-2010 (an ACE value of 152.5).

Reference: Saunders, M. A., Klotzbach, P. J., Lea, A. S. R., Schreck, C. J., & 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

## MDR, Caribbean Sea and Gulf of Mexico ACE Index & System Numbers in 2021

| | | ACE Index | Intense Hurricanes | Hurricanes | Tropical Storms |
|---|---|---|---|---|---|
| TSR Forecast | 2021 | 116 | 3 | 6 | 12 |
| 71-yr Climate Norm | 1950-2020 | 82 | 2 | 4 | 8 |
| 10-yr Climate Norm | 2011-2020 | 94 | 2 | 5 | 10 |
| Forecast Skill at this Lead | 2003-2020 | 14% | 10% | 26% | 25% |

The Atlantic hurricane <u>M</u>ain <u>D</u>evelopment <u>R</u>egion (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.

There is a 62% probability that the 2020 Atlantic hurricane season ACE index will be above-average (defined as an ACE index value in the upper tercile historically (>96)), a 26% likelihood it will be near-normal (defined as an ACE index value in the middle tercile historically (45 to 96) and a 12% chance it will be below-normal (defined as an ACE index value in the lower tercile historically (<45)). The 71-year period 1950-2020 is used for climatology.

## USA Landfalling ACE Index and Numbers in 2021

| | | ACE Index | Hurricanes | Tropical Storms |
|---|---|---|---|---|
| TSR Forecast | 2021 | 2.8 | 2 | 5 |
| 71-yr Climate Norm | 1950-2020 | 2.5 | 1 | 3 |
| 10-yr Climate Norm | 2011-2020 | 2.6 | 2 | 4 |
| Forecast Skill at this Lead | 2003-2020 | 0% | 11% | 14% |

Key: ACE Index = <u>A</u>ccumulated <u>C</u>yclone <u>E</u>nergy 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 2020 the USA landfalling ACE index will be above average (defined as a USA ACE index value in the upper tercile historically (>2.5)), a 29% likelihood it will be near-normal (defined as a USA ACE index value in the middle tercile historically (1.1 to 2.5)) and a 26% chance it will be below-normal (defined as a USA ACE index value in the lower tercile historically (<1.1)). The 71-year period 1950-2020 is used for climatology.

## Methodology and Key Predictor(s) for 2021

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.

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.

The TSR pre-season forecast for North Atlantic hurricane activity in 2021 calls for ACE-activity that is ~30-35% above the long-term norm because of three factors that are anticipated to enhance hurricane activity. These factors are (1) the April-May-June 2021 North Atlantic Oscillation (NAO); (2) the July-August-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); (3) the August-September forecast SST for the tropical North Atlantic (region 10°N–20°N, 20°W–60°W). We anticipate that the April-June NAO 2021 value will be in the lower quartile of years 1965-2020 when the April-June ENSO ONI (Oceanic Nino Index) is neutral. The current forecast for the July-September trade wind is for $0.59 \pm 0.64$ ms$^{-1}$ weaker than normal (1981-2010 climatology) which is slightly weaker than the April 2021 forecast value of $0.53 \pm 0.80$ ms$^{-1}$ weaker than normal. The current forecast for the August-September SST is for $0.35 \pm 0.30$°C warmer than normal (1981-2010 climatology) which is slightly warmer than the April 2021 forecast value of $0.25 \pm 0.33$°C warmer than normal. A moderately negative April-June NAO when ENSO is neutral is associated with enhanced North Atlantic hurricane numbers and with enhanced U.S. landfalling hurricane activity. 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. However, it should be stressed that uncertainties in the forecast for North Atlantic hurricane activity in 2021 remain sizeable at this lead of two-to-three months before the start of the main hurricane season in mid-August. These uncertainties surround in particular the strength of the July-September 2021 trade winds and how warm the tropical North Atlantic will be in August-September 2021.

## Precision of Seasonal Hurricane Forecasts 2003-2020 Issued in Real-Time

The figure on the next page displays the seasonal forecast skill for North Atlantic hurricane activity for the 18-year period between 2003 and 2020. This skill assessment uses the seasonal forecast values that were issued publicly in real-time by the three forecast centres TSR, CSU (Colorado State University) and NOAA (National Oceanic and Atmospheric Administration). Skill is displayed as a function of lead time for two measures of seasonal hurricane activity: the ACE index and basin hurricane numbers.

The Mean Square Skill Score (MSSS) is used to define the forecast skill. MSSS 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 after 2011.

It is clear there is little skill in forecasting the upcoming ACE and numbers of hurricanes from the previous December for the period 2003-2020. Skill starts to climb after April as the hurricane season approaches with moderate-to-good skill levels being achieved, on average, by early August.
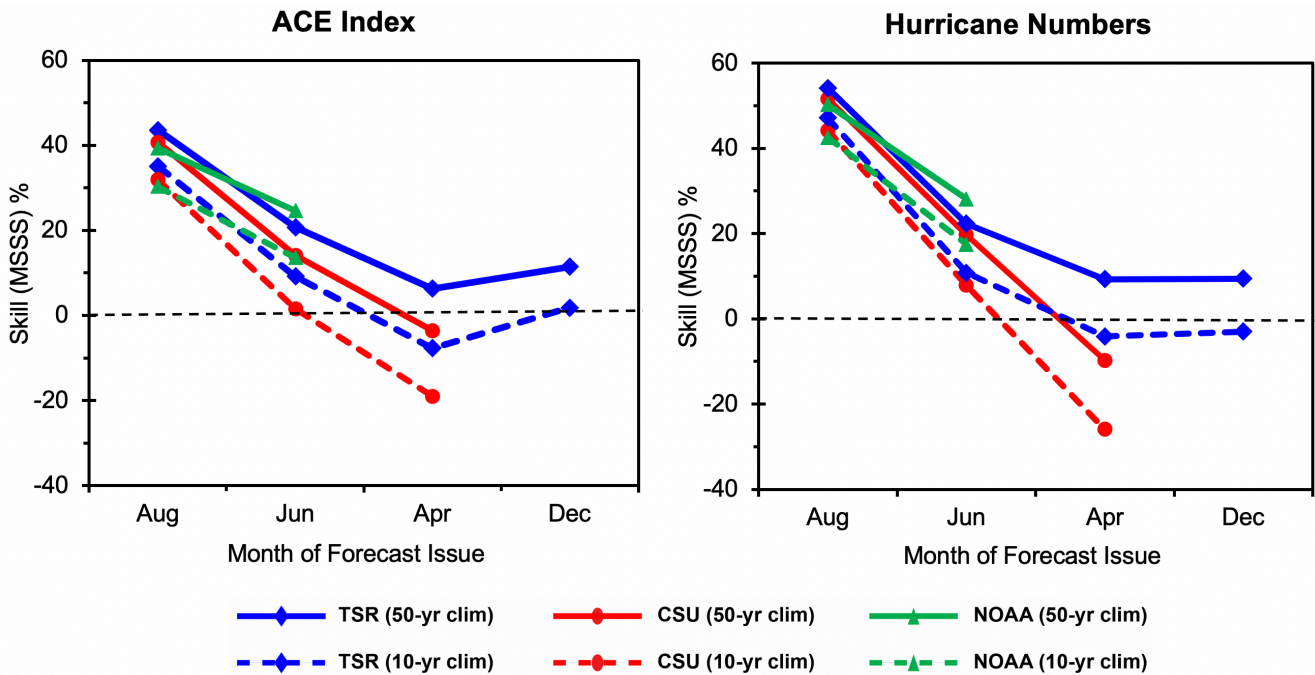


Although there are mostly only small differences in skill between the three forecast centres, the TSR model has been either the near-equal best or the best performing statistical seasonal forecast model at all lead times for the period 2003-2020.

## 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 next TSR forecast update for the 2021 North Atlantic hurricane season will be issued on Tuesday 6th July 2021.

## Appendix – Predictions from Previous Months

### 1. Atlantic ACE Index and System Numbers

| Atlantic ACE Index and System Numbers 2021 | | ACE Index | Named Tropical Storms | Hurricanes | Intense Hurricanes |
|---|---|---|---|---|---|
| Average Number (1950-2020) | | 105 | 12 | 6 | 3 |
| Average Number (2011-2020) | | 123 | 17 | 7 | 3 |
| TSR Forecasts | 27 May 2021 | 140 | 18 | 9 | 4 |
| | 13 April 2021 | 134 | 17 | 8 | 3 |
| | 9 December 2020 | 127 | 16 | 7 | 3 |
| CSU Forecast | 8 April 2021 | 150 | 17 | 8 | 4 |
| NOAA Forecast | 20 May 2021 | 106-184 | 13-20 | 6-10 | 3-5 |
| Met Office Forecast* | 20 May 2021 | 117 | 14 | 7 | 3 |

*Refers to activity between 1st June 2021 and 30th November 2021 only.

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

| MDR, Caribbean Sea and Gulf of Mexico ACE Index and Numbers 2021 | | | | | |
|---|---|---|---|---|---|
| | | ACE Index | Named Tropical Storms | Hurricanes | Intense Hurricanes |
| Average Number (1950-2020) | | 82 | 8 | 4 | 2 |
| Average Number (2011-2020) | | 94 | 10 | 5 | 2 |
| TSR Forecasts | 27 May 2021 | 116 | 12 | 6 | 3 |
| | 13 April 2021 | 114 | 11 | 6 | 3 |

## 3. US ACE Index and Landfalling Numbers

| US Landfalling Numbers 2021 | | | | |
|---|---|---|---|---|
| | | ACE Index | Named Tropical Storms | Hurricanes |
| Average Number (1950-2020) | | 2.5 | 4 | 2 |
| Average Number (2011-2020) | | 2.6 | 4 | 2 |
| TSR Forecasts | 27 May 2021 | 2.8 | 5 | 2 |
| | 13 April 2021 | 2.5 | 4 | 2 |