# Examining Hurricane Ida's Impact on Mental Health: Results from a Quasi-Experimental Analysis

**Luke Wertis**[1], **Jennifer D. Runkle**[2] , **Margaret M. Sugg**[1], **Devyani Singh**[3]

[1] Department of Geography and Planning, Appalachian State University, Boone, NC USA, [2] NC Institute for Climate Studies, NC State University, Raleigh, NC, USA, [3] Research & Impact Team, Crisis Text Line, New York City, New York

Key Points:

- Examining the changes in crisis help-seeking individuals in Louisiana, USA, during a concurrent disaster period following Hurricane Ida.
- Ida led to a sustained increase in stress/anxiety, thoughts of suicide, and bereavement.
- Findings support the use of crisis text lines in post-disaster mental health support and surveillance efforts.

**ABSTRACT:** Limited research has evaluated the mental health effects of compounding disasters (e.g., hurricanes followed by a heat wave), and few studies have relied on crisis lines for post-disaster mental health surveillance. This study examined changes in crisis help-seeking for individuals in Louisiana, USA, before and after Hurricane Ida (2021), a storm that co-occurred during the COVID-19 pandemic, subsequent hurricane, and corresponding heatwave. An interrupted time series analysis for a single and multiple group comparisons were used to examine pre-and post- changes in crisis text volume (any crisis text, substance use, thoughts of suicide, stress/anxiety and bereavement) among help-seeking individuals in communities that received individual and public assistance disaster declarations. Results showed a significant increase in crisis texts for any reason, thoughts of suicide, stress/anxiety, and bereavement in the short-term impact period. In the continued impact period, there was an increase in crisis texts for any crisis event, substance use, thoughts of suicide, stress/anxiety, and bereavement. Findings highlight the need for more mental health support for residents directly impacted by concurrent disasters.

Keywords: Climate disaster, Mental health, Crisis text line, ARIMA, Difference-in-Difference, Concurrent Disasters, Interrupted Time Series Analysis, Thoughts of Suicide, stress/anxiety, Substance use, Bereavement

## 1. Introduction

A robust evidence base shows that as climate change continues, there will be an increase in the intensity and frequency of extreme events, like hurricanes (Kossin et al., 2020). Climate hazards have the potential to co-occur with other geographically or temporally located climate hazards (e.g., heat waves following a hurricane) with significant potential to amplify mental health risks (Dodgen et al., 2016). Since the early 1980s, significant changes in the

intensity, frequency, and duration of North Atlantic hurricanes have been observed (Kossin et al., 2010; Walsh et al., 2014). A recent NOAA report concludes that both the intensity and associated rainfall of tropical cyclones are likely to increase during the 21st century due to anthropogenic climate change, although it is too soon to conclusively attribute observed changes to human activity (Knutson et al., 2019). Exposure-response patterns indicate that increased and direct exposure to climate disaster events yields an increase in mental health consequences in the impacted population post-hurricane, including anxiety (Costa et al., 2009; Weems 2016), thoughts of suicide, and suicidal ideation (Fitzpatrick et al., 2020; Kessler et al., 2006; Runkle et al., 2020), bereavement (Cunsolo et al., 2018; Shear et al., 2011), and substance use (Rowe et al., 2008).

The COVID-19 pandemic is a health-induced disaster, with cases in the U.S as high as 39.6 million and deaths reaching 650,000 as of August 2021. The pandemic co-occurred with several climate-driven disasters in the U.S., including Hurricane Laura (2020), Western wildfires (2020), and Hurricane Ida (2021). To date, there is little known about the mental health impacts of concurrent disasters, although researchers have highlighted the potential for more negative and severe impacts (Quigley et at., 2020). Limited research on crisis events from climate disasters during the COVID-19 pandemic has shown that the COVID-19 pandemic is the primary driver of crisis outcomes rather than large-scale disasters like the 2020 Western US Wildfires (Sugg et al., 2021). The potential for intersecting health risks of the COVID-19 pandemic and climate-related changes in tropical storms, like Hurricane Ida, include the amplification of COVID-19 infection rates, a reduction in COVID-19 vaccination rates, and other adverse health effects related to direct exposure or cascading effects from hurricane damage (e.g., loss of power or affordable housing) (Shulz et al. 2022).

The objective of this retrospective interrupted time-series study was to evaluate pre- and post-changes in crisis-support-seeking patterns among people impacted in Louisiana during and following Hurricane Ida in August 2021. Ida resulted in a loss of power for nearly 1 million

Louisiana residents in the days following the storm and over 76 billion dollars in damage (Comstock O, 2021). The power outage coincided with Hurricane Nicholas (September 15, 2021) and a heatwave placing vulnerable residents at risk for heat-health complications that also resulted in multiple heat-related deaths (Childs J, 2021). All of these events occurred during the COVID-19 pandemic, which still resulted in over 197,000 cases and 2,900 deaths in Louisiana from August to September 2021.

We hypothesize that the compounding events (defined as spatially and temporally co-occurring climate extremes)–Hurricane Ida followed by Hurricane Nicholas and a severe heatwave–resulted in excess mental health burden for the directly impacted population in the acute impact phase (i.e., four months post-disaster) (Singh et al., 2022). As methods are still evolving to examine compounding disasters, we employed two separate quasi-experimental designs, the difference-in-difference (DID) model and the interventional autoregressive integrated moving average (ARIMA), to study the causal impact of Hurricane Ida on crisis response in the backdrop of elevated crisis response brought on by the pandemic and other climate-induced disasters. Our results will provide new knowledge on the causal impact of crisis events from Hurricane Ida, a storm that co-occurred with Hurricane Nicholas, a deadly heatwave, and the COVID-19 pandemic.

## 2. **Methods**:

### 2.1 *Storm impact on the study area*

Hurricane Ida (August 26 - September 3, 2021) made landfall in the United States near Port Fourchon, Louisiana, as a Category 4 hurricane with maximum sustained winds of 150 mph. It became the second-most damaging and intense hurricane to make landfall in Louisiana, behind Hurricane Katrina (2005). Hurricane Ida moved quickly over the state of Louisiana but

not before leaving 5 to 10 inches of rain across impacted areas, with some areas receiving as much as 15 inches of rain. There was heavy damage to the energy infrastructure across southern Louisiana, causing widespread, long-duration power outages to millions of people across the state; additionally, wireless services were temporarily out because of the storm (Rossenthal, 2021). As a result of the rainfall, several levies were overtopped in Jefferson and Plaquemines Parish (Wetly, 2021). LA received a disaster declaration for Ida on Aug 29, 2021, whereby every county in the state was eligible to receive public assistance and the counties in the lower Capital (Region 2), South Central (Region 3), Northshore (Region 9), and Greater New Orleans (Region 1) areas were eligible for public and individual assistance from FEMA. The NOAA National Centers for Environmental Information (NCEI) estimated damages from wind and water during Ida resulted in $76.5 billion in losses (e.g., societal disruptions, property damage) and 96 deaths (National Centers for Environmental Information, 2022).

*Concurrent events*. Tropical Storm Nicholas (Sept 12 to 18, 2021) was a slow-moving, category one storm that occurred within two weeks of Ida (Lato et al., 2022). Nicholas brought heavy rainfall ranging from 4 to 8 inches for south-central parishes in LA, and widespread flooding occurred throughout the southern part of the state. A disaster declaration was declared on Sept 13, 2021, and FEMA designated every county in the state as eligible for individual assistance (FEMA, 2021). In addition to record-setting Ida, and flooding events, LA experienced a record-breaking summer–NOAA recorded July 2021 as the hottest month for the globe on record (NOAA, 2021). Following Ida and the sustained power outages, the National Weather Service lowered the threshold criteria and issued several heat advisories and warnings to reduce the risk of heat-related morbidity and mortality for residents during the post-impact period. The resulting heatwave was attributed to more deaths, than Hurricane Ida (The New York Times, 2021). At the time of Ida, COVID-19 cases were on the decline following a surge in early August 2021, but at the time of the storm, inpatient hospitalizations for COVID-19 were

higher than at any other point of the pandemic (Treisman, 2021). COVID-19 response efforts were slowed due to the evacuation of healthcare facilities following storm damage.

### 2.2 *Crisis-text data*

Anonymized data from Crisis Text Line (CTL)—a non-profit organization that provides free, 24/7 crisis counseling services via text messaging across the US—was used to study crisis help-seeking patterns. This data has previously been used to understand the relationship between crisis-help seeking in response to temperature extremes (Sugg et al., 2019), wildfires (Sugg et al., 2021a), Hurricane Florence (Runkle et al., 2021), and the COVID-19 pandemic (Runkle et al., 2022; Sugg et al., 2021b). When using this service, an individual is connected with a trained volunteer Crisis Counselor via text message. Immediately following each conversation, CTL asks its volunteer counselors to complete a report on each conversation, which is completed after 95% of the conversations. Crisis Counselors identify issues discussed in the conversation from a list of topics ('issue tags') and assign data labels to the bivariate (yes/no) 'issue tags' (e.g., stress/anxiety, thoughts of suicide, bereavement) from a list of 17 options (at the time of this study). A conversation can be labeled with multiple 'issues tags.' The primary issue tags used in this analysis were the following bivariate (yes/no) crisis concerns: any crisis text (daily sum of any crisis tag), substance use, thoughts of suicide, stress/anxiety, and bereavement.

Daily CTL conversation counts were aggregated for the five area codes of Louisiana for all of 2021; four of those represented the impacted area that was used as the focus for this study (i.e., 504, 985, 225, 337), while the fifth was used as the control group (i.e., 318). The control group was restricted to Louisiana so that both groups were under the same political structure and disaster support, which changes as you cross state lines (Domingue et al., 2019; Malmin, 2020; Schmidtlein et al., 2008). All CTL data used in this study were anonymized and

de-identified, and daily text volumes for ‘texter issues’ were aggregated to protect the privacy of CTL users. Data on demographic characteristics were available for a subset of approximately 20% of the users who provided these details in an optional post-conversation survey; however, these data were not included in our analysis due to the small sample size.

### 2.3 *Pre- and post-hurricane temporal periods*

The study period occurred from Jan 1 to Dec 29, 2021. The pre-Ida period was defined as Jan 1 to Aug 28, 2021, and the post-Ida period was Aug 29 to Dec 29, 2021. To evaluate the change in crisis text volume following Ida, we examined three different time periods, (1) the short-term impact period, four weeks after the storm (Aug 29, 2021, to Sep 29, 2021); (2) the delayed impact period, three months after the storm, (Aug 29, 2021, to Nov 29, 2021); and (3) the continued impact period, four months following the storm, (Aug 29, 2021, to Dec 29, 2021). The time series included 363 days of crisis-text observations, 240 days of pre-Ida data, and 123 days of post-Ida data.

### 2.4 *Statistical analysis*

Descriptive statistics were performed to examine the mean daily CTL volume with a 95% confidence interval for each pre-and post-hurricane temporal period for the impacted and control groups. A paired t-test (continuous data) and chi-square test (categorical data) were used to determine whether the mean daily CTL text volume for each ‘texter issue’ differed by the pre-and post- Ida period ($\boldsymbol{\alpha}$ = 0.05) for each intervention group (i.e., impacted, control).

#### 2.4.1 *Interrupted time series analysis*

We performed an interrupted time series (ITS) analysis to capture the immediate and gradual impact of crisis text volume for individuals in Louisiana before and after the impact of Ida. AutoRegressive Integrated Moving Average (ARIMA) models were used to analyze daily CTL volume and address autocorrelation between daily time series for each crisis tag (Schaffer et al., 2021). ARIMA models make very few assumptions and are a very flexible class of time series models that allow for pre-and post-event hypothesis testing (Ho et al., 1998). We examined various ARIMA models, and the best fit was assessed by using a four-step process: 1) evaluate the autocorrelation function (ACF) and partial autocorrelation function (PACF); 2) use an algorithm, auto.arima (Hyndman et al., 2022), to determine the ideal autoregressive terms (*p*), the number of nonseasonal differences needed for stationarity (*d*), and the number of lagged forecast errors in the prediction equation (*q*); 3) determine by manually adjusting the *p*, *d*, and *q* values if another ideal combination exists for the Ljung-Box test and distribution of the model residuals; and 4) evaluate the Akaike Information Criterion (AIC) score from the algorithm and the manually adjusted ARIMA model to determine the simplest and best-fit model (one that explains the greatest amount of variation using the fewest possible independent variables). Comparisons were made fitting combinations of the Step, Ramp, and Pulse functions to determine if these provide better results (Schaffer et al., 2021). The base ARIMA was shown to have the lowest AIC score and was determined to be the best fit for predicting future text volume four months after Ida. Forecasting was used in the ARIMA model to generate predicted text volume for the time series based on pre-Ida data to compare the actual versus predicted volume of daily text in the post-Ida period. Analysis was done in R packages *astsa* (David Stoffer, 2021), *forecast* (Hyndman et al., 2022), and *stats* (R Core Team, 2021) using R version 4.2.0 (2022-04-22).

2.4.2 *Comparative - ITS*

One disadvantage of the use of interventional ARIMA in ITS is the inability to differentiate changes originating from one treatment when co-occurring within another (e.g., Hurricane Ida within the same time as COVID-19) (Sugg et al., 2021). Thus, in an effort to minimize the potential confounding of co-occurring events, we also included control (i.e., counterfactual) locations where Hurricane Ida did not impact populations in the same manner (Turner et al., 2020). ARIMA (1,0,1) was also computed on locations not impacted by Hurricane Ida. This comparative ITS design is typically not done in other ITS analysis. As few as one-fourth of ITS studies include some form of external control (Turner et al., 2020). Comparative ARIMA models were constructed for the control region, and forecasted results were compared to observed values ($\boldsymbol{\alpha}$ = 0.10).

2.4.3 *Difference-in-Difference (DID) analysis*

Difference-in-difference (DID) is a separate ITS design performed for analyses of longitudinal data on treatment and control groups to obtain an appropriate counterfactual to estimate the causal effect of an intervention on long-term health outcomes for the impacted population compared to the control (Cao et al., 2011; Hersche et al., 2011; Wing et al., 2018). DID is typically used to estimate the effect of a specific intervention or treatment, such as a new policy, or drug implementation, by differencing the changes in outcomes over time between the population as impacted (intervention group) and the control group (Stuart et al., 2014). Unlike the ARIMA analysis, DID allows for the inclusion of control group(s) (i.e., counterfactual) (Callaway et al., 2021 [a]).

For this analysis, CTL data were restricted to area codes that were exposed and unexposed (control) to determine the first difference. A second difference examined the temporal pre-/post- comparator following the timeframe of the hurricane event (post-event) compared to the time frame before the hurricane event (pre-event) (Babu et al., 2017). We used

the Callaway and Sant'Anna difference-in-difference approach with multiple time periods because, unlike in the traditional DID method, this method allows for multiple staggered time periods to be examined at once (Callaway et al., 2021[a]). In our study, the Average Treatment Effect on Treated (ATT) was constructed for each crisis concern separately. After constructing the ATT variable, which contained all the results for group-time average treatment effects, the Aggregated Group-Time Average Treatment Effects (which aggregates each variable into a smaller number of parameters) was performed to allow for multiple time periods post-treatment to be observed. Analysis was done in the R package *did* (Callaway et al., 2021[b]) using R version 4.2.0 (2022-04-22).

## 3. **Results**:

### 3.1 *Descriptive Statistics of Study Population*

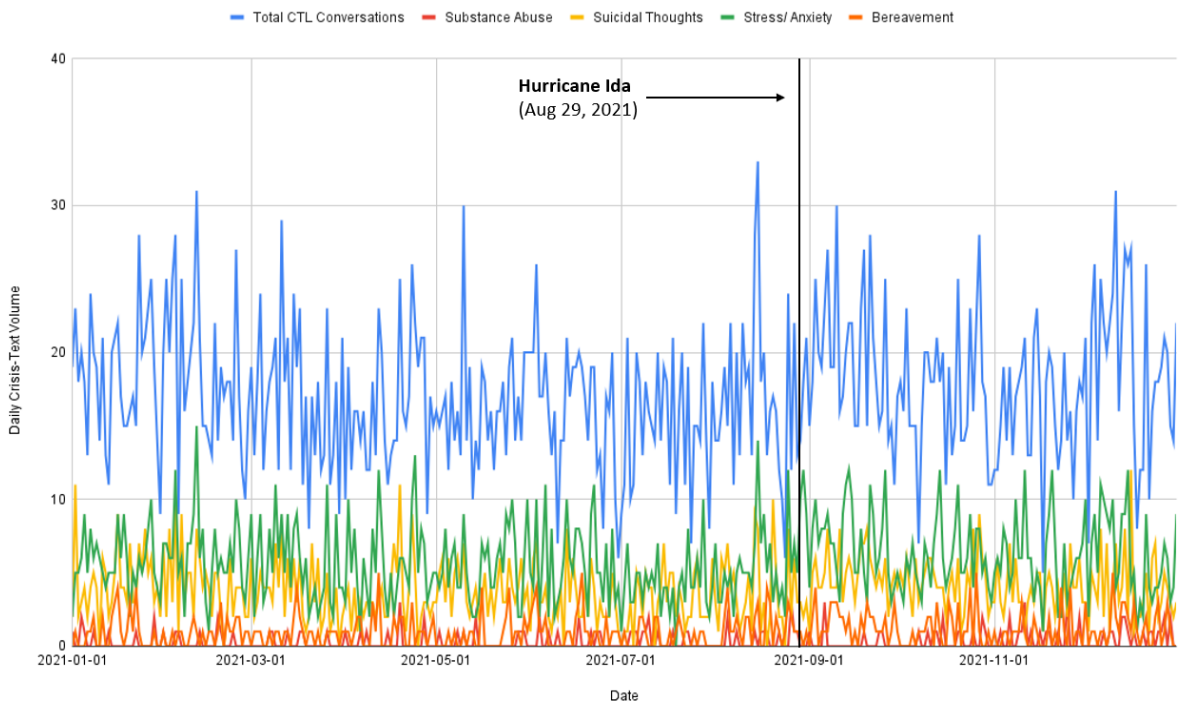


Fig. 1. Daily crisis text volume for all CTL conversations, substance abuse, suicidal thoughts, stress/anxiety, and bereavement before (Jan 1, 2021) and after (Aug 29, 2021) Hurricane Ida, Louisiana.

Table 1 shows the demographic characteristics and crisis issues for the impacted and control locations. Crisis texters in LA who reported demographic information were generally female, LGBTQ+, and White. In impacted areas, the proportion of texters who reported thoughts of suicide and stress/anxiety increased in the post-impact period. Figure 1 shows the daily CTL text volume for each outcome for the time series (Jan 01 to Dec 29, 2021). Daily total CTL conversations peaked 12 and 21 days after the storm, while thoughts of suicide peaked around days 60 and 110, substance use peaked on day 9, and again around day 74, stress/anxiety peaked around days 2 and 17, and bereavement peaked on day 59 post-Ida.

Table 1. Summary of daily crisis-text volume and demographics of Louisiana communities impacted before and after Hurricane Ida, 2021. Pre-Ida: Jan 1 - Aug 28, 2021; Post-Ida: Aug 29 - Dec 29 2021

| Demographics | | Impacted group | | | Control group | | |
|---|---|---|---|---|---|---|---|
| | | Pre-Ida | Post-Ida | p-value | Pre-Ida | Post-Ida | p-value |
| | | n = 4067 | n = 2215 | | n = 1035 | n = 588 | |
| Gender (%) | Female | 933 (22.9) | 393 (17.7) | <0.001 | 229 (22.1) | 111 (18.8) | 0.013 |
| | Male | 171 (4.2) | 57 (2.6) | | 21 (2.0) | 12 (2.0) | |
| | Nonconforming | 194 (4.8) | 109 (4.9) | | 21 (2.0) | 22 (3.7) | |
| | No Answer | 2769 (68.1) | 1656 (74.8) | | 763 (73.8) | 444 (75.4) | |
| Race and Ethnicity (%) | Asian | 10 (0.2) | 1 (0.0) | 0.001 | 8 (0.8) | 4 (0.7) | 0.1 |
| | Black | 321 (7.9) | 144 (6.5) | | 65 (6.3) | 37 (6.3) | |
| | White | 518 (12.7) | 219 (9.9) | | 133 (12.9) | 63 (10.7) | |
| | Hispanic | 92 (2.3) | 44 (2.0) | | 5 (0.5) | 1 (0.2) | |
| | Indigenous American | 14 (0.3) | 6 (0.3) | | 5 (0.5) | 6 (1.0) | |
| | Middle Eastern | 3 (0.1) | 0 (0.0) | | 0 (0.0) | 0 (0.0) | |
| | Other Mixed Race | 238 (5.9) | 121 (5.5) | | 19 (1.8) | 7 (1.2) | |
| | No Answer | 2871 (70.6) | 1680 (75.8) | | 799 (76.2) | 471 (80.0) | 0.004 |
| Sexual Identity (%) | LGBTQ+ | 530 (13.0) | 238 (10.7) | <0.001 | 113 (10.9) | 41 (7.0) | |
| | Straight | 619 (15.2) | 217 (9.8) | | 147 (14.2) | 88 (14.9) | |
| | No Answer | 2918 (71.7) | 1760 (79.5) | | 774 (74.9) | 460 (78.1) | |
| Age (%) | 13 or younger | 113 (2.8) | 62 (2.8) | 0.002 | 54 (5.2) | 19 (3.2) | 0.032 |
| | 14-17 | 417 (10.3) | 178 (8.0) | | 58 (5.6) | 49 (8.3) | |
| | 18-24 | 241 (5.9) | 124 (5.6) | | 66 (6.4) | 39 (6.6) | |
| | 25-34 | 254 (6.2) | 102 (4.6) | | 45 (4.4) | 29 (4.9) | |
| | 35-44 | 49 (1.2) | 45 (2.0) | | 11 (1.1) | 6 (1.0) | |
| | 45-54 | 52 (1.3) | 38 (1.7) | | 12 (1.2) | 13 (2.2) | |
| | 55-64 | 10 (0.2) | 5 (0.2) | | 2 (0.2) | 1 (0.2) | |
| | 65+ | 8 (0.2) | 4 (0.2) | | 0 (0.0) | 0 (0.0) | |
| | No Answer | 2923 (71.9) | 1657 (74.8) | | 786 (76.1) | 433 (73.5) | |
| Conversation Concern | | | | | | | |
| Any Text | | 4067 | 2215 | | 1035 | 588 | |
| Substance Use | | 81 (0.02) | 45 (0.02) | 0.065 | 21 (0.02) | 6 (0.09) | 0.052 |
| Thoughts of Suicide | | 895 (0.22) | 532 (0.24) | 0.141 | 238 (0.42) | 135 (0.42) | 0.892 |
| Stress and Anxiety | | 1342 (0.33) | 775 (0.35) | 0.143 | 352 (0.48) | 188 (0.47) | 0.268 |
| Bereavement | | 204 (0.05) | 155 (0.07) | 0.042 | 73 (0.25) | 53 (0.29) | 0.048 |

Table 2 demonstrates the mean text volume from pre-Ida (baseline) compared to the three post-intervention periods using paired t-tests: short-term impact (i.e. four weeks), delayed impact (i.e. three months), and continued impact (i.e. four months) post-storm. We observed significantly more crisis text frequency for all texts (20.41 daily conversations), thoughts of suicide (5 daily conversations), stress/anxiety (7.56 daily conversations), as well as bereavement (1.56 daily conversations) in the four weeks after Ida compared to the pre-event period. Daily text volume for thoughts of suicide (4.37 daily conversations), stress/anxiety (6.32 daily conversations) were significantly higher in the first three months after the storm compared to the pre-hurricane period. Daily text volume for any text (18.02 daily conversations), substance

use (0.45 daily conversations), thoughts of suicide (4.29 daily conversations), stress/anxiety (6.3 daily conversations), and bereavement (1.23 daily conversations) were significantly higher during the continued impact compared to the pre-hurricane period.

Table 2. Summary of daily crisis text from impacted communities in Louisiana before and after Hurricane Ida, 2021.

| Daily Text Volume | Pre-Ida mean (95%CI) (Jan1 - Aug 28) | Post-Ida mean | | |
|---|---|---|---|---|
| | | Short-term impact (95%CI) (Aug 29 - Sep 26) | Delayed impact (95%CI) (Aug 29 - Nov 29) | Continued impact (95%CI) (Aug 29 - Dec 29) |
| Any Text | 16.81 (12.08, 21.54) | 20.41*** (15.97, 24.85) | 17.6 (13.0, 22.2) | 18.02* (13.01, 23.03) |
| Substance Use | 0.3 (-0.28, 0.88) | 0.26 (-0.4, 0.92) | 0.41 (0.32, 1.14) | 0.45* (-0.28, 1.18) |
| Thoughts of Suicide | 3.7 (1.52, 8.88) | 5** (3.31, 6.69) | 4.37** (2.65, 6.09) | 4.29* (2.33, 6.25) |
| Stress and Anxiety | 5.56 (2.92, 8.20) | 7.56*** (4.97, 10.15) | 6.32* (3.75, 8.89) | 6.3* (3.62, 8.98) |
| Bereavement | 0.92 (-0.16, 2.0) | 1.56** (0.51, 2.61) | 1.18 (-.02, 2.38) | 1.23* (0.01, 2.25) |

* p-value <0.05
** p-value < 0.01
*** p-value < 0.001

3.2 *ARIMA models for Crisis Text Line Volume post-Ida*

The base ARIMA (1,0,1) model was the best-fit model to examine the pre-/post Hurricane Ida change in daily crisis text counts. No seasonal lag was observed in daily crisis text volume within the period examined and seasonality was not adjusted for in the models.

Table 3 shows the estimated conversation volume for each of the three different hurricane post-event periods: short-term impact, delayed impact, and continued impact. The model

predicted an increase of 3%, 0%, 3.5%, 3.6%, and 6.5% in conversation volume for any reason, thoughts of suicide, stress/anxiety, and bereavement, respectively, in the short-term impact (i.e., four weeks). For the delayed impact period (i.e., three months), crisis texts were predicted to increase by 1.3%, 10%, 5.1%, 3.6%, and 7.6% for any reason, thoughts of suicide, stress/anxiety, and bereavement, respectively, compared to their pre-Ida volume. In the continued impact (i.e., four months), the conversation volume was predicted to increase by 3%, 16.7%, 5.1%, 4.3%, and 10.9% for any reason, thoughts of suicide, stress/anxiety, and bereavement, respectively, compared to the pre-Ida volume.

Table 3. ARIMA (1,0,1) model parameter characteristics for each crisis text outcome in Louisiana communities post-Ida under different impact scenarios, Crisis Text Line 2021.

| | Model 1 (Short-term impact) | | Model 2 (Delayed impact) | | Model 3 (Continued impact) | |
|---|---|---|---|---|---|---|
| | Estimate (SE) | p-Value | Estimate (SE) | p-Value | Estimate (SE) | p-Value |
| Any Text | 17.32(0.65) | <0.001 | 17.03(0.43) | <0.001 | 17.23(0.41) | <0.001 |
| AR 1 | 0.94(0.07) | <0.001 | 0.90(0.1) | <0.001 | 0.85(0.09) | <0.001 |
| MA 1 | -0.81(0.10) | <0.001 | -0.82(0.13) | <0.001 | -0.75(0.12) | <0.001 |
| Substance Use | 0.30(0.04) | <0.001 | 0.33(0.03) | <0.001 | 0.35(0.03) | <0.001 |
| AR 1 | -0.44(0.69) | 0.53 | 0.53(0.32) | 0.1 | -0.52(0.78) | 0.51 |
| MA 1 | 0.46(0.68) | 0.5 | -0.59(0.31) | 0.05 | 0.54(0.79) | 0.49 |
| Thoughts of Suicide | 3.83(0.13) | <0.001 | 3.89(0.11) | <0.001 | 3.89(0.11) | <0.001 |
| AR 1 | -0.82(0.15) | <0.001 | -0.83(0.14) | <0.001 | -0.76(0.23) | <0.001 |
| MA 1 | 0.76(0.17) | <0.001 | 0.78(0.16) | <0.001 | 0.69(0.25) | <0.01 |
| Stress and Anxiety | 5.76(0.2) | <0.001 | 5.76(0.17) | <0.001 | 5.8(0.17) | <0.001 |
| AR 1 | 0.48(0.40) | 0.23 | 0.17(0.33) | 0.6 | 0.27(0.29) | 0.35 |
| MA 1 | -0.33(0.43) | 0.43 | -0.01(0.33) | 0.99 | -0.09(0.3) | 0.75 |
| Bereavement | 0.98(0.08) | <0.001 | 0.99(0.07) | <0.001 | 1.02(0.06) | <0.001 |
| AR 1 | -0.06(0.31) | 0.85 | -0.03(0.79) | 0.97 | -0.28(0.32) | 0.39 |
| MA 1 | 0.26(0.30) | 0.39 | 0.13(0.76) | 0.86 | 0.39(0.31) | 0.21 |

Model 1: Short-term impact *(Aug 29 - Sep 26)*
Model 2: Delayed impact *(Aug 29 - Nov 29)*
Model 3: Chronic impact *(Aug 29 - Dec 29)*

Shocks to the daily crisis text rate for each outcome in the four months after the storm were felt in subsequent days following the storm (Figure. 2a–e). We observed a 16.4%, 26.5%, 27%, and 46% increase in crisis texts for any reason, thoughts of suicide, stress/anxiety, and

bereavement, respectively, in the short-term period (i.e., four weeks) after Ida compared to the forecasted amount. In the delayed impact (i.e., three months) following Ida, there was an 11.6% and 9.3% increase in crisis text for thoughts of suicide and stress/anxiety compared to the predicted volume. In the continued impact (i.e., four months) following Ida, there was a 4.5%, 25%, 9.8%, 8.3%, and 18.7% increase in crisis texts for any reason, substance use, thoughts of suicide, stress/anxiety, and bereavement, respectively, compared to the forecasted amount.

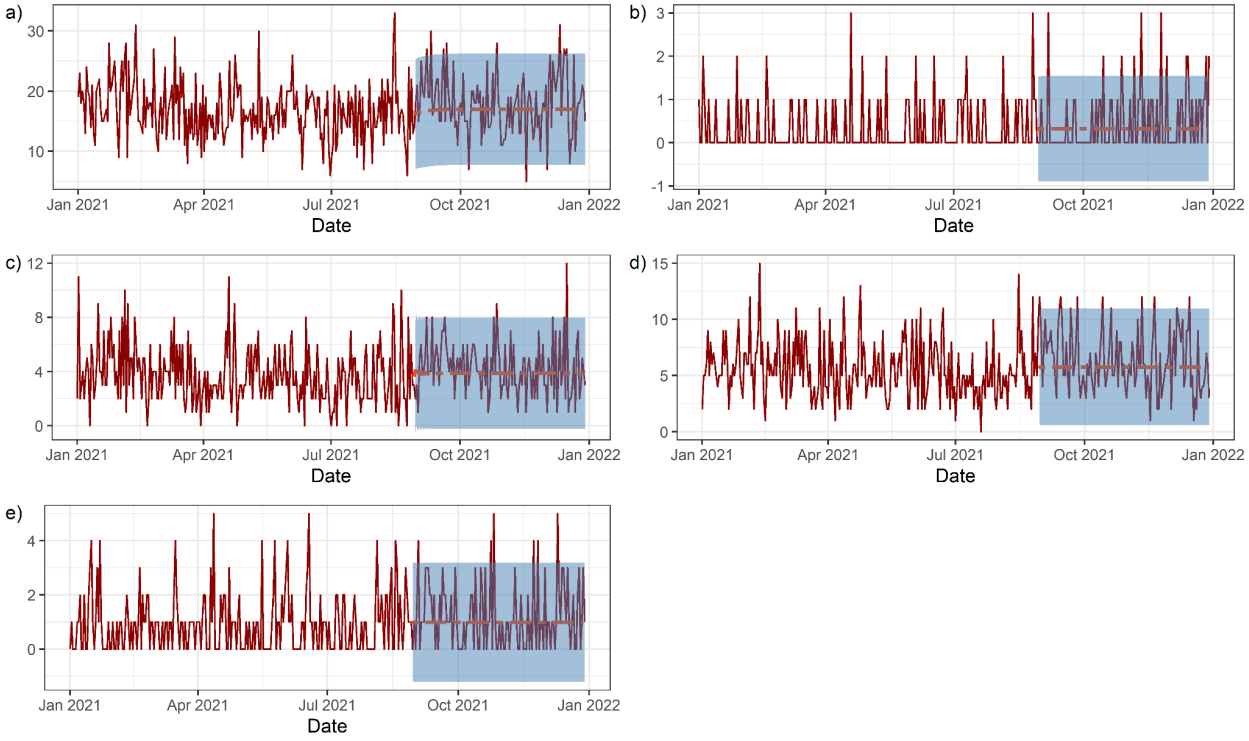



Figure 2 shows the forecasted crisis text volume in the four-month post-Ida intervention period for (a) any text; (b) substance use; (c) thoughts of suicide; (d) stress/anxiety; (e) bereavement, Louisiana 2021. The dotted red line shows the forecasted amount of conversations and the transparent blue square represents the 95% confidence interval.

3.3 *Forecast modeling of a control group*

Table 5. ARIMA (1,0,1) model parameter characteristics for each crisis text outcome in the control Louisiana communities post-Ida under different impact scenarios, Crisis Text Line 2021.

| | Model 1 (Short-term impact) | | Model 2 (Delayed impact) | | Model 3 (Continued impact) | |
|---|---|---|---|---|---|---|
| | Estimate (SE) | p-Value | Estimate (SE) | p-Value | Estimate (SE) | p-Value |
| Any Text | 4.32(0.15) | <0.001 | 4.34(0.13) | <0.001 | 4.43(0.13) | <0.001 |
| AR 1 | -0.32(0.30) | 0.26 | -0.34(0.31) | 0.28 | -0.19(0.43) | 0.66 |
| MA 1 | 0.44(0.27) | 0.11 | 0.44(0.30) | 0.13 | .30(0.42) | <0.47 |
| Substance Use | 0.09(0.02) | <0.001 | 0.08(0.02) | <0.001 | 0.07(0.02) | <0.001 |
| AR 1 | -059(0.39) | <0.001 | -0.57(0.36) | <0.001 | -0.59(0.41) | <0.001 |
| MA 1 | 0.65(0.36) | <0.001 | 0.63(0.34) | <0.001 | 0.64(0.39) | <0.001 |
| Thoughts of Suicide | 1.02(0.06) | <0.001 | 0.98(0.06) | <0.001 | 1.02(0.06) | <0.001 |
| AR 1 | -0.02(1.76) | 0.99 | -0.09(0.83) | 0.92 | 0.04(0.48) | 0.94 |
| MA 1 | 0.03(1.75) | 0.99 | 0.11(0.83) | 0.90 | 0.02(0.48) | 0.97 |
| Stress and Anxiety | 1.50(0.07) | <0.001 | 1.47(0.06) | <0.001 | 1.49(0.06) | <0.001 |
| AR 1 | -0.59(0.56) | 0.38 | -0.27(0.64) | 0.67 | -0.32(0.59) | 0.58 |
| MA 1 | 0.42(0.59) | 0.47 | 0.22(0.65) | 0.73 | 0.28(0.60) | 0.63 |
| Bereavement | 0.29(0.03) | <0.001 | 033(0.03) | <0.001 | 0.34(0.03) | <0.001 |
| AR 1 | 0.17(3.16) | 0.96 | 0.19 | | 0.39 | |
| MA 1 | -0.16(3.20) | 0.96 | -0.19 | | -0.37 | |

Model 1: Short-term impact *(Aug 29 - Sep 26)*
Model 2: Delayed impact *(Aug 29 - Nov 29)*
Model 3: Chronic impact *(Aug 29 - Dec 29)*

Table 5 shows the ARIMA(1,0,1) model estimated conversation volume of daily future crisis text volume for individuals in Louisiana post-Ida for each intervention period for non-impacted areas. These areas were observed to determine if the trends in the impacted areas were being seen in non-exposed locations across the state (counterfactuals) (Figure. 3a–e). Using ARIMA, significantly more crisis text frequency was observed for any text in the four weeks (i.e., short-term impact) and four months (i.e., continued impact) after Ida compared to the pre-event period, 18% and 6.9% respectively compared to the predicted volume. Significantly more crisis text frequency was observed for bereavement in the three months (39%), and four months (i.e., continued impact) (28.6%) after Ida compared to the pre-event period compared to the forecasted amount. The impacted and control group saw an equal rise in text volume for any

reason in the first four weeks (i.e., short-term impact) after Ida. However, when there was a significant increase in overall text volume and the rate of increase was higher in the control group. Indicating that the rise in overall crisis help-seeking behavior and bereavement rates were not isolated to just the impacted areas.

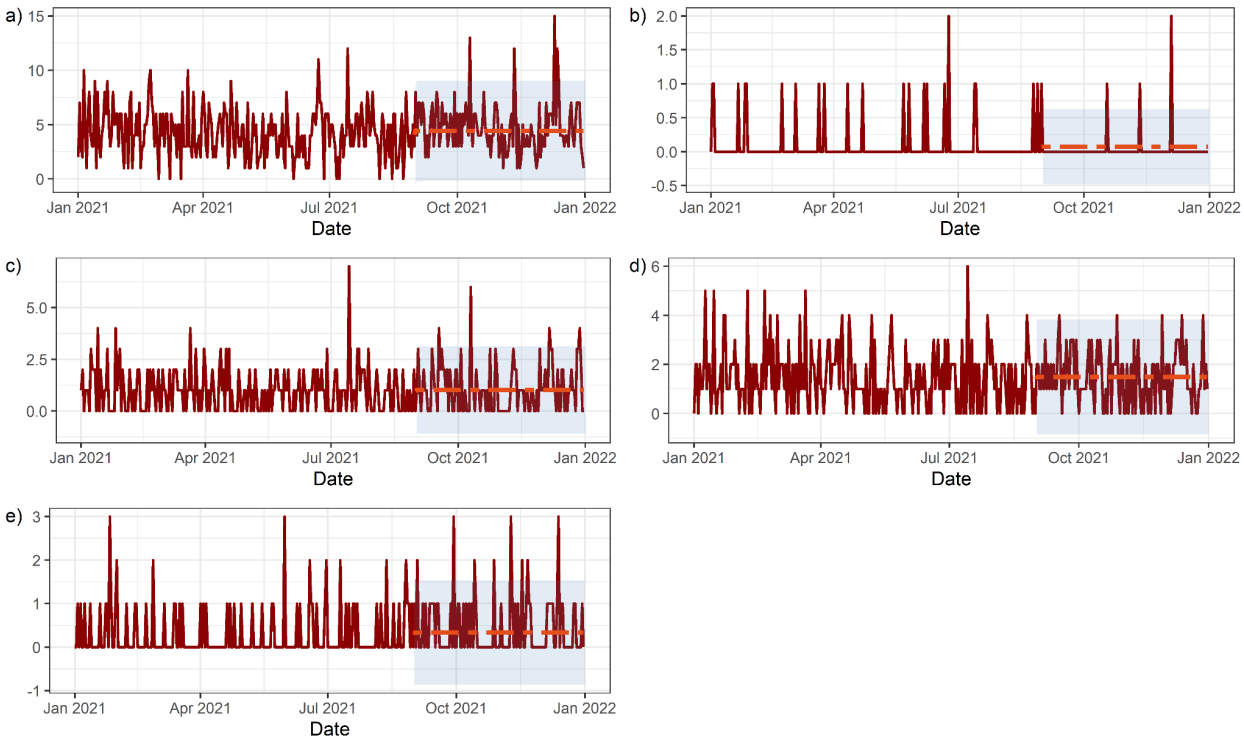



Figure 3 shows the forecasted crisis text volume of the control group in the four-month post-Ida intervention period for (a) any text; (b) substance use; (c) thoughts of suicide; (d) stress/anxiety; (e) bereavement, Louisiana 2021. The dotted red line shows the forecasted amount of conversations and the transparent blue square represents the 95% confidence interval.

### 3.4 *Difference-in-Difference models for Crisis Text Line Volume post-Ida*

The impact model results for each crisis outcome for the different hurricane event scenarios are shown in Table 4. We observed a significant positive percent difference in texter volume in the impacted group compared to the control group for substance use (0.03, CI: 0.03-0.04) and stress/anxiety (0.13, CI: 0.02-0.24) in the short-term impact (i.e., four weeks) period following

the storm. In the delayed impact (i.e., three months) period following the storm, there was a significant increase in texter volume for the impacted group compared to the control group for substance use (0.08, CI: 0.06, 0.09), thoughts of suicide (0.19, CI: 0.10-0.27), and stress/anxiety (0.12, CI: 0.07-0.16). In the continued impact (i.e. four months) period following Hurricane Ida, there was a significant positive percent difference for people texting about substance use (0.08, CI: 0.04-0.12).

Table 4. Summary of the average effect of treatment on the treated (ATT) for Louisiana impacted compared to control communities before and after Hurricane Ida, 2021.

| | Post-Ida ATT | | |
|---|---|---|---|
| Daily Text Volume | Short-term impact (95%CI) (Aug 29, 2021 - Sep 26, 2021) | Delayed impact (95%CI) (Sep 27, 2021 - Nov 29, 2021) | Continued impact (95%CI) (Nov 30, 2021 - Dec 29, 2021) |
| Any Text | 0.0227 | 0.0020 | -0.0743* |
| | ( -0.1612, 0.2066) | (-0.0425, 0.0466) | (-0.1120, -0.0365) |
| Substance Use | 0.0313* | 0.0754* | 0.0822* |
| | (0.0262, 0.0363) | (0.0559, 0.0948) | (0.0449, 0.1194) |
| Thoughts of Suicide | -0.0152 | 0.1858* | -0.1620* |
| | ( -0.1403, 0.1100) | (0.0969, 0.2747) | ( -0.2257, -0.0983) |
| Stress and Anxiety | 0. 1336* | 0. 1174* | 00137 |
| | (0. 0246, 0. 2425) | (0. 0698, 0.1649) | (-0.0883, 0.1156) |
| Bereavement | 0.0026 | -0.0784* | -0.0271 |
| | (-0.0406, 0.0457) | ( -0.1202, -0.0366) | (-0.1181, 0.0639) |

* p-value <0.05
** p-value < 0.01
*** p-value < 0.001

## 4. Discussion:

The objective of this study was to examine the mental health impacts of concurrent disasters on residents of impacted communities in Louisiana, including Hurricane Ida, which co-occurred with Hurricane Nicholas, a deadly heatwave, and the COVID-19 pandemic. Results confirm our hypothesis that Hurricane Ida generated an immediate and sustained increase in crisis text patterns for stress/anxiety, and a significant peak in substance abuse and thoughts of

suicide texts among individuals directly impacted compared to those in the control group in the three months following Hurricane Ida. Our ITS results were supported by a DID analysis examining changes in crisis-text volume among those impacted by Hurricane Ida compared to a control group for multiple timer periods post-storm. After accounting for temporal changes in local crisis text patterns, we concluded that the initial and sustained increase in the average daily volume of crisis-texts post-disaster is likely reflective of the mental health experience of impacted individuals in Louisiana associated with Hurricane Ida complicated by the strain of the pandemic and perhaps the lower magnitude, but wider impacts of Hurricane Nicholas and extreme heat advisories.

In a study concerning preschool-aged children's mental health following Hurricane Florence, researchers found that high hurricane impact predicted a significant increase in PTSD symptoms one year after the storm (Naudé et al., 2022). Limited research has examined shorter impact impacts of climate disasters on mental health. Similar climate disaster research using CTL data has linked Hurricane Florence to a 23% increase in thoughts of suicide and a 17% increase in stress/anxiety in the first 6 weeks following the event among youth populations directly exposed (Runkle et al., 2021). Our ITS results are comparable with 26.5% increases in thoughts of suicide and 27% increases in stress/anxiety in the first four weeks following the storm. However, Hurricane Ida impacted a different region (Louisiana) and co-occurred with other extremes (i.e., heatwave, COVID-19), which may explain higher rates of crisis events in our short-term impact period.

Following Hurricane Sandy in New York, there was an increase in reported instances of depression and stress for the first 6 months and a continuous increase in reported cases of post-traumatic stress disorder in the first year. In both cases, areas that experienced flooding had a significantly higher increase in reported instances of mental health impact compared to sites that experienced no flooding (He et al., 2016; Lieberman-Cribbin et al., 2017; Schneider et al., 2019; Schwartz et al., 2017). Although our analysis did not incorporate a 6-month time

period, we did note increases in crisis events up to four months in our ITS and DID analysis for substance abuse in areas that were directly impacted by the storm. Conversely, our control regions experienced a significant increase in crisis events, suggesting “spillover” effects from Hurricane Ida (e.e, via media exposure) or continued mental health concerns from the concurrent COVID-19 pandemic.

Researchers interviewingHurricane Katrina adult survivors 5 to 8 months after the storm determined that severe and moderate-mild forms of mental illness were 5.2% and 10.2% higher, respectively, compared to the pre-Katrina period (Kessler et al., 2006). Conversely, participants with a preexisting mental illness exposed to Katrina reported a decline of 7.7% in suicidal ideation and a 2.9% reduction in suicidal plans post-Katrina. A sample of the initial interviewees participated in a follow-up interview 1 year after the storm, and PTSD symptoms, severe mental illness, suicidal ideation, and suicidal plans were all significantly higher, 6%, 3.1%, 3.6%, and 1.5% respectively, than pre-Katrina reported numbers (Kessler et al., 2008). Our ITS and DID results showed a similar trend in overall mental health, but we detected an earlier peak in daily text volume for thoughts of suicide in the first three months following Hurricane Ida.

Community and individual mental health response to natural disasters is influenced by the size and magnitude of the disaster event, visibility of impact, the degree of personal exposure ( e.g., loss of loved ones, home, fabric of community), and the probability of recurrence (DeWolfe 2000). In general, the results of our study align with previous research indicating a rise in mental health concerns regarding stress/anxiety in the first six months following a hurricane (Lieberman-Cribbin et al., 2017; Runkle et al., 2021), despite the occurrence of multiple co-occurring disasters (e.e., heat wave, COVID-19 pandemic) during our study period. Our findings are similar to the first stage of the model proposed by DeWolfe and utilized by the US Substance Abuse and Mental Health Administration (SAMHSA) for community disaster response, which states that the survivors’ emotions generally become more difficult to manage around the time of a disaster warning, and feelings of distress and

uncertainty continue to increase until the impact of the disaster. However, our findings are in contrast with the model once we move further out from the disaster event and look at the one to four months post-event period that coincides with the heroic phase or response. The SAMHSA model states that the emotions and mental health response of victims will generally improve during the heroic or acute recovery phase, in which they are motivated to contribute to the disaster response, which allows them to better manage their stress while their motivations are focused on recovery (DeWolfe et al., 2000). Interestingly, results from the DID and ARIMA analysis show a peak in anxiety/stress texts in the one month after the storm, followed by a sustained increase in stress/anxiety and significantly higher text volume for thoughts of suicide and substance abuse in the three months post-storm. Our results suggest that the climate-driven hurricane may have worsened or amplified the effect of the pandemic characterized by an already elevated volume of crisis response in LA, which may have served to shorten the heroic or honeymoon period and ushered in disillusionment more quickly.

Our data contrasts with previous work that suggests either an improvement in mental health in the immediate term following a climate-driven disaster (DeWolfe et al., 2000), a drop in suicidality post-disaster (Kõlves et al., 2013), or as much as a 6-month to 1-year delay in symptom appear (PTSD, depression, suicidal ideation) following a natural disaster (Galea et al., 2007; Kessler et al., 2008; Naudé et al., 2022), these differences might be attributable to the differences in methodological approaches across studies, including delays in characterizing mental health symptoms using a survey with significant time lag since the initial disaster event versus daily digital text responses before, during, and throughout the post-impact period. Our focused analysis of data from a text-based platform, which provides a more immediate method of capturing the psychological response of individuals compared to traditional survey methodologies coupled with pre-intervention texter patterns, may explain why our results differ from previous research.

*Recommendations for Post-Disaster Mental Health Response*

The majority of communities impacted by a climate disaster in Louisiana were characterized as health professional shortage areas, meaning that these areas typically do not have enough professional counselors to provide residents with the mental health care services they need after a disaster, particularly immediately following the acute impact period (Dodgen et al., 2016). Reaching impacted communities in the immediate wake (2 to four weeks) of a climate disaster with professional counselors has been shown to reduce the risk of long-term mental health concerns even in extreme cases such as Katrina, and addressing these issues early has a continuing effect across time (Bui et al., 2021; Weems et al., 2009). Further, it has been noted that contact with sources of social support outside of the family predicted lower levels of self-reported symptoms of post-traumatic stress disorder, anxiety, and depression post-Katrina (Pina et al., 2008). Additionally, The Committee on Post-Disaster Recovery of a Community's Public Health indicates the need for counseling goes beyond the immediate aftermath of a natural disaster and that there is a need for long-term mental health services for mental health symptoms that develop 6 months to several years post-event (National Academies Institute of Medicine, 2015). For these reasons, it is encouraging that our results suggest individuals are willing to seek help during an acutely vulnerable time through a text-based crisis counseling platform (i.e., Crisis Text Line) to address their distress versus a more traditional and potentially less accessible, clinic-based service. We recommend the use of digital platforms like Crisis Text Line during these climate disasters as a potential intervention for the mitigation of mental health effects from climate disasters.

## 4.1 Strengths and Limitations

This study contributes to the existing literature in several significant ways. First, unlike the previous mental health research (Galea et al., 2007; Kessler et al., 2008; Naudé et al., 2022; Pia et al., 2008), which focused on survey responses, psychometric screening scales, and clinical interviews, our study uses an interrupted time-series design to account for pre-event trends in help-seeking behaviors and better characterize the post-impact of the disaster (i.e., level, slope, and changing pattern) on crisis response help-seeking (Hudson et al., 2019). Additional strengths included the analysis of daily counts for texting behavior for a large array of mental health concerns, from a nationally available crisis text platform, compared to weekly or monthly counts of hospital or emergency department use data that will not be readily available to the research community for at least a year after the event. ARIMA models also allow for the adjustment of autocorrelation to account for the delayed influence of crisis texts for a particular outcome earlier in the time-series. Additionally, the DID analysis addressed the potential for uncontrolled confounding variables by adding a control group that allows for a comparison of how the impacted group differed had they not been exposed (Wing et al., 2018).

The study had a few limitations. The aggregate level exposure to Hurricane Ida estimated in our study at the area code level did not equate to hurricane exposure based on FEMA-designated disaster declarations for impacted counties. To ensure that all impacted Parishes were included in our study, there were several unimpacted Parishes that had to be included due to the extent of the area code reaching into a few unimpacted Parishes. Further, due to the use of aggregated and de-identified crisis text data, we were unable to discern the effect of preexisting mental health conditions (e.g., previous diagnosis of anxiety or depression) on changes in post-Ida conversation volume. Research has shown that the mental health consequences of a disaster among survivors with a pre-existing mental health condition are more severe compared to individuals with new and emergent psychological sequelae (SAMHSA 2019; Storch et al., 2018). Lastly, the post-intervention periods in our analysis were defined over a short period of time, four weeks, three months, and four months post-intervention. Previous

studies have found a sustained increase in mental health concerns as long as 24 months after the hurricane (Olteanu et al., 2011; Roberts et al., 2010). Future work is needed across longer time scales to assess the impacts of hurricanes as well as concurrent disasters.

Future research is needed to confirm our findings in the context of other hurricanes impacting the Southeast and consider the mental health impacts of other climate and social disasters co-occurring with each other (e.g., COVID-19, heatwave, and wildfire). Analysis of the health impacts from concurrent disasters is still an emerging research priority and requires expansion beyond the traditional single hazard approach. Continued reliance on models that only explain how individuals are impacted by a single hazard will not be sufficient as the climate continues to change ushering in the more frequent incidence of multiple and co-occurring hazard events in quick succession (Potutan et al., 2021).

### 4.2 Conclusions

This study is amongst the first to examine the concurrent effects of mental health during the 2021 hurricane season and the ongoing COVID-19 pandemic and co-occurrent heatwave. Our study leveraged a real-time anonymized data set of national crisis events in the U.S. that allowed us to examine pre-and post-event crisis response to both Hurricane Ida and the COVID-19 pandemic. We implemented a quasi-experimental framework to investigate the trends in crisis events using both an interrupted time series analysis and difference in difference modeling approach. Our results showed statistically significant increases in several CTL-crisis events in the short-term, delayed, and continued impact scenarios (i.e. four weeks, three months, four months) following Hurricane Ida. More research is needed to understand the complex time-varying effects of concurrent and cascading climate disasters across different populations and regions, and for concurrent disasters.

CRediT authorship contribution statement

Luke Wertis: Conceptualization, Data Curation, Methodology, Formal analysis, Writing - original draft, Visualization, Software, Writing - review & editing. Margaret M. Sugg: Conceptualization, Methodology, Writing - review & editing. Jennifer D. Runkle: Conceptualization, Methodology, Writing - review & editing. Devyani Singh: Writing - review & editing.

Declaration of competing interest

Devyani Singh is employed by Crisis Text Line. However, the authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank our external funders and collaborators for supporting this work. This work is made possible through the collaboration with Crisis Text Line and the funded support of the National Institute of Environmental Health Sciences (NIEHS)'s R15 grant, "A Causal Analysis of the Complex Mental Health Impacts of the Climate Crisis in Young People" (2021-2024). The content is solely the authors' responsibility and does not represent the official views of Crisis Text Line, or the National Institute of Environmental Health Sciences.

References

1. Kossin, J. P., Knapp, K. R., Olander, T. L., & Velden, C. S. (2020). Global increase in major tropical cyclone exceedance probability over the past four decades. *Proceedings of the National Academy of Sciences*, *117*(22), 11975–11980. https://doi.org/10.1073/pnas.1920849117

2. Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., & Somerville, R. (2014). Ch. 2: Our changing climate. Climate change impacts in the United States: The Third national climate assessment. https://doi.org/10.7930/j0kw5cxt
3. Kossin, J. P., Camargo, S. J., & Sitkowski, M. (2010). Climate modulation of North Atlantic Hurricane tracks. *Journal of Climate*, *23*(11), 3057–3076. https://doi.org/10.1175/2010jcli3497.1
4. Knutson, T., Camargo, S. J., Chan, J. C., Emanuel, K., Ho, C.-H., Kossin, J., Mohapatra, M., Satoh, M., Sugi, M., Walsh, K., & Wu, L. (2019). Tropical cyclones and climate change assessment: Part I: Detection and attribution. *Bulletin of the American Meteorological Society*, *100*(10), 1987–2007. https://doi.org/10.1175/bams-d-18-0189.1
5. Potutan, G., & Arakida, M. (2021). Evolving Disaster Response Practices during COVID-19 Pandemic. *International Journal of Environmental Research and Public Health*, *18*(6), 3137. https://doi.org/10.3390/ijerph18063137
6. Quigley, M. C., Attanayake, J., King, A., & Prideaux, F. (2020). A multi-hazards Earth science perspective on the COVID-19 pandemic: The potential for concurrent and cascading crises. *Environment Systems and Decisions*, *40*(2), 199–215. https://doi.org/10.1007/s10669-020-09772-1
7. Dodgen, D., Donato, D., Kelly, N., La Greca, A., Morganstein, J., Reser, J., … & Ursano, R. (2016). Ch. 8: Mental Health and Well-being (pp. 217-246). US Global Change Research Program, Washington, DC.
8. Shultz, J. M., Trapido, E. J., Kossin, J. P., Fugate, C., Nogueira, L., Apro, A., Patel, M., Torres, V. J., Ettman, C. K., Espinel, Z., & Galea, S. (2022). Hurricane Ida's impact on Louisiana and Mississippi during the COVID-19 delta surge: Complex and compounding threats to Population Health. *The Lancet Regional Health - Americas*, *12*, 100286. https://doi.org/10.1016/j.lana.2022.100286
9. Costa, N. M., Weems, C. F., & Pina, A. A. (2009). Hurricane Katrina and youth anxiety: The role of perceived attachment beliefs and parenting behaviors. *Journal of Anxiety Disorders*, *23*(7), 935–941. https://doi.org/10.1016/j.janxdis.2009.06.002
10. Weems, C. F., Russell, J. D., Neill, E. L., Berman, S. L., & Scott, B. G. (2016). Existential anxiety among adolescents exposed to disaster: Linkages among level of exposure, PTSD, and depression symptoms*. *Journal of Traumatic Stress*, *29*(5), 466–473. https://doi.org/10.1002/jts.22128
11. Kessler, R. (2006). Mental illness and suicidality after Hurricane Katrina. *Bulletin of the World Health Organization*, *84*(12), 930–939. https://doi.org/10.2471/blt.06.033019
12. Runkle, J. D., Michael, K. D., Stevens, S. E., & Sugg, M. M. (2021). Quasi-experimental evaluation of text-based crisis patterns in youth following Hurricane Florence in the Carolinas, 2018. *Science of The Total Environment*, *750*, 141702. https://doi.org/10.1016/j.scitotenv.2020.141702
13. Fitzpatrick, K. M., & Spialek, M. L. (2020). Suicide ideation and a post-disaster assessment of risk and protective factors among hurricane harvey survivors. *Journal of Affective Disorders*, *277*, 681–687. https://doi.org/10.1016/j.jad.2020.08.072
14. Shear, M. K., McLaughlin, K. A., Ghesquiere, A., Gruber, M. J., Sampson, N. A., & Kessler, R. C. (2011). Complicated grief associated with Hurricane Katrina. *Depression and Anxiety*, *28*(8), 648–657. https://doi.org/10.1002/da.20865
15. Cunsolo, A., & Ellis, N. R. (2018). Ecological grief as a mental health response to climate change-related loss. *Nature Climate Change*, *8*(4), 275–281. https://doi.org/10.1038/s41558-018-0092-2
16. Rowe, C. L., & Liddle, H. A. (2008). When the levee breaks: Treating adolescents and families in the aftermath of Hurricane Katrina. *Journal of Marital and Family Therapy*, *34*(2), 132–148. https://doi.org/10.1111/j.1752-0606.2008.00060.x
17. Comstock, O. (2021, September 15). *Hurricane Ida caused at least 1.2 million electricity customers to Lose Power*. Homepage - U.S. Energy Information Administration (EIA). Retrieved May 4, 2022, from https://www.eia.gov/todayinenergy/detail.php?id=49556#:~:text=Hurricane%20Ida%20resulted%20in%20service,and%20Emergency%20Response%20(CESER)

18. Childs, J. (2021, September 9). *Heat is biggest killer in Louisiana after Hurricane Ida: The weather channel - articles from The Weather Channel*. The Weather Channel. Retrieved May 4, 2022, from https://weather.com/news/news/2021-09-09-heat-hurricane-ida-new-orleans-louisiana-power-outages
19. Singh, J., Ashfaq, M., Skinner, C. B., Anderson, W. B., Mishra, V., & Singh, D. (2022). Enhanced risk of concurrent regional droughts with increased ENSO variability and warming. *Nature Climate Change*, *12*(2), 163–170. https://doi.org/10.1038/s41558-021-01276-3
20. Latto, A. S., & Center, R. (2022). HURRICANE NICHOLAS. *NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT*. Retrieved from https://www.nhc.noaa.gov/data/tcr/AL142021_Nicholas.pdf.
21. *It's official: July was Earth's hottest month on record*. National Oceanic and Atmospheric Administration. (2021, August 13). Retrieved June 28, 2022, from https://www.noaa.gov/news/its-official-july-2021-was-earths-hottest-month-on-record
22. Bogel-burroughs, N., & Reckdahl, K. (2021, September 15). *The greatest killer in New Orleans wasn't the hurricane. it was the heat.* The New York Times. Retrieved August 1, 2022, from https://www.nytimes.com/2021/09/15/us/new-orleans-hurricane-ida-heat.html#:~:text=t%20the%20Hurricane.-,It%20Was%20the%20Heat
23. Treisman, R. (2021, August 30). *Louisiana and Mississippi were overwhelmed by covid-19 cases. then Ida Struck*. NPR. Retrieved June 28, 2022, from https://www.npr.org/2021/08/30/1032441006/storm-ida-covid-19-surge-louisiana-mississippi-hospitals-vaccines
24. *Designated areas: Disaster 3574*. Designated Areas | FEMA.gov. (n.d.). Retrieved June 28, 2022, from https://www.fema.gov/disaster/3574/designated-areas
25. Sugg, M. M., Runkle, J. D., Hajnos, S. N., Green, S., & Michael, K. D. (2022). Understanding the concurrent risk of mental health and dangerous wildfire events in the COVID-19 pandemic. *Science of The Total Environment*, *806*, 150391. https://doi.org/10.1016/j.scitotenv.2021.150391
26. Turner, S. L., Karahalios, A., Forbes, A. B., Taljaard, M., Grimshaw, J. M., Cheng, A. C., Bero, L., & McKenzie, J. E. (2020). Design characteristics and statistical methods used in interrupted time series studies evaluating Public Health Interventions: A Review. *Journal of Clinical Epidemiology*, *122*, 1–11. https://doi.org/10.1016/j.jclinepi.2020.02.006
27. Schaffer, A. L., Dobbins, T. A., & Pearson, S.-A. (2021). Interrupted time series analysis using autoregressive integrated moving average (ARIMA) models: A guide for evaluating large-scale health interventions. *BMC Medical Research Methodology*, *21*(1). https://doi.org/10.1186/s12874-021-01235-8
28. David Stoffer (2021). astsa: Applied Statistical Time Series Analysis. R package version 1.14. https://CRAN.R-project.org/package=astsa
29. Hyndman R, Athanasopoulos G, Bergmeir C, Caceres G, Chhay L, O'Hara-Wild M, Petropoulos F, Razbash S, Wang E, Yasmeen F (2022). _forecast: Forecasting functions for time series and linear models_. R package version 8.16, <URL: https://pkg.robjhyndman.com/forecast/>.
30. R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
31. Turner, S. L., Karahalios, A., Forbes, A. B., Taljaard, M., Grimshaw, J. M., Cheng, A. C., Bero, L., & McKenzie, J. E. (2020). Design characteristics and statistical methods used in interrupted time series studies evaluating Public Health Interventions: A Review. *Journal of Clinical Epidemiology*, *122*, 1–11. https://doi.org/10.1016/j.jclinepi.2020.02.006
32. Cao, Z., & Song, X. (2011). SB1 comparison of difference-in-difference, propensity score matching and instrumental variables in estimating cost differences between two cohorts. Value in Health, 14(3). https://doi.org/10.1016/j.jval.2011.02.025
33. Hersche, M., & Moor, E. (2020). Identification and estimation of intensive margin effects by difference-in-difference methods. Journal of Causal Inference, 8(1), 272–285. https://doi.org/10.1515/jci-2019-0035

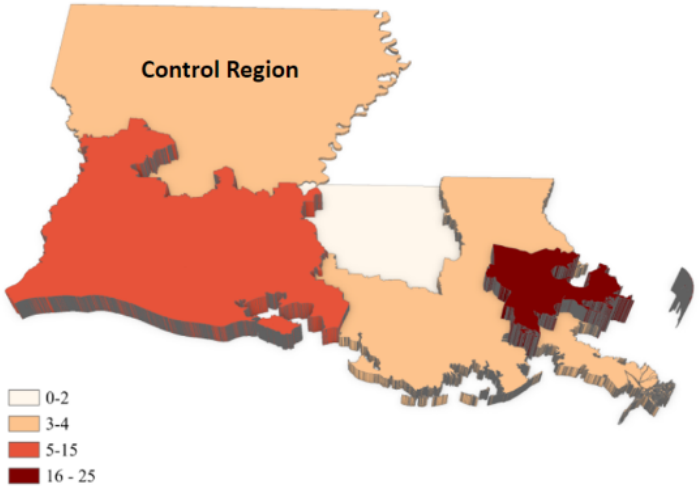
34. Wing, C., Simon, K., & Bello-Gomez, R. A. (2018). Designing difference in difference studies: Best practices for public health policy research. Annual Review of Public Health, 39(1), 453–469. https://doi.org/10.1146/annurev-publhealth-040617-013507
35. Stuart, E. A., Huskamp, H. A., Duckworth, K., Simmons, J., Song, Z., Chernew, M. E., & Barry, C. L. (2014). Using propensity scores in difference-in-differences models to estimate the effects of a policy change. Health Services and Outcomes Research Methodology, 14(4), 166–182. https://doi.org/10.1007/s10742-014-0123-z
36. Callaway, B., & Sant'Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. Journal of Econometrics, 225(2), 200–230. https://doi.org/10.1016/j.jeconom.2020.12.001
37. Babu, S. C., & Hallam, A. (2017). Chapter 11 - Methods of Program Evaluation: An Analytical Review and Implementation Strategies. In S. N. Gajanan (Ed.), *Nutrition Economics* (pp. 205–230). essay, Academic Press.
38. Callaway B, Sant'Anna P (2021). "did: Difference in Differences." R package version 2.1.1, <https://bcallaway11.github.io/did/>.
39. Schaffer, A. L., Dobbins, T. A., & Pearson, S. A. (2021). Interrupted time series analysis using autoregressive integrated moving average (ARIMA) models: a guide for evaluating large-scale health interventions. *BMC medical research methodology*, *21*(1), 58. https://doi.org/10.1186/s12874-021-01235-8
40. Schmidtlein, M. C., Finch, C., & Cutter, S. L. (2008). Disaster declarations and major hazard occurrences in the united states∗. *The Professional Geographer*, *60*(1), 1–14. https://doi.org/10.1080/00330120701715143
41. Domingue, S. J., & Emrich, C. T. (2019). Social vulnerability and procedural equity: Exploring the distribution of disaster aid across counties in the United States. *The American Review of Public Administration*, *49*(8), 897–913. https://doi.org/10.1177/0275074019856122
42. Malmin, N. P. (2020). Historical disaster exposure and household preparedness across the United States. *Disaster Medicine and Public Health Preparedness*, *15*(1), 58–64. https://doi.org/10.1017/dmp.2019.123
43. Ho, S. L., & Xie, M. (1998). The use of Arima models for reliability forecasting and analysis. *Computers & Industrial Engineering*, *35*(1-2), 213–216. https://doi.org/10.1016/s0360-8352(98)00066-7
44. Welty, Chris (August 29, 2021). "Levee overtops in Braithwaite". *WGNO*. Archived from the original on August 29, 2021. Retrieved August 29, 2021. https://www.ncei.noaa.gov/access/monitoring/billions/events
45. Rosenthal, Zachary. "True scope of Ida's destruction becoming clearer in wake of storm". AccuWeather. Archived from the original on August 31, 2021. Retrieved August 31, 2021.
46. "Billion-Dollar Weather and Climate Disasters: Events". Asheville, North Carolina: National Centers for Environmental Information. January 10, 2022. Archived from the original on January 11, 2022. Retrieved January 10, 2022.
47. Pina, A. A., Villalta, I. K., Ortiz, C. D., Gottschall, A. C., Costa, N. M., & Weems, C. F. (2008). Social Support, discrimination, and coping as predictors of posttraumatic stress reactions in youth survivors of Hurricane Katrina. *Journal of Clinical Child & Adolescent Psychology*, *37*(3), 564–574. https://doi.org/10.1080/15374410802148228
48. Bui, B. K., Anglewicz, P., & VanLandingham, M. J. (2021). The impact of early social support on subsequent health recovery after a major disaster: A longitudinal analysis. *SSM - Population Health*, *14*, 100779. https://doi.org/10.1016/j.ssmph.2021.100779
49. Naudé, A. R., Machlin, L., Furlong, S., & Sheridan, M. A. (2022). Threat responsivity predicts posttraumatic stress disorder hyperarousal symptoms in children after Hurricane Florence. *Cognitive, Affective, & Behavioral Neuroscience*. https://doi.org/10.3758/s13415-022-00984-3
50. He, F. T., Lundy De La Cruz, N., Olson, D., Lim, S., Levanon Seligson, A., Hall, G., Jessup, J., & Gwynn, C. (2016). Temporal and spatial patterns in utilization of mental health services during and after Hurricane Sandy: Emergency department and Inpatient Hospitalizations in New York City.

*Disaster Medicine and Public Health Preparedness*, *10*(3), 512–517. https://doi.org/10.1017/dmp.2016.89

51. Schneider, S., Rasul, R., Liu, B., Corry, D., Lieberman-Cribbin, W., Watson, A., Kerath, S. M., Taioli, E., & Schwartz, R. M. (2019). Examining posttraumatic growth and mental health difficulties in the aftermath of Hurricane Sandy. *Psychological Trauma: Theory, Research, Practice, and Policy*, *11*(2), 127–136. https://doi.org/10.1037/tra0000400
52. Schwartz, R. M., Gillezeau, C. N., Liu, B., Lieberman-Cribbin, W., & Taioli, E. (2017). Longitudinal impact of Hurricane Sandy exposure on mental health symptoms. *International Journal of Environmental Research and Public Health*, *14*(9), 957. https://doi.org/10.3390/ijerph14090957
53. Lieberman-Cribbin, W., Liu, B., Schneider, S., Schwartz, R., & Taioli, E. (2017). Self-reported and FEMA flood exposure assessment after Hurricane Sandy: Association with Mental Health Outcomes. *PLOS ONE*, *12*(1). https://doi.org/10.1371/journal.pone.0170965
54. Kessler, R. (2006). Mental illness and suicidality after Hurricane Katrina. *Bulletin of the World Health Organization*, *84*(12), 930–939. https://doi.org/10.2471/blt.06.033019
55. Kessler, R. C., Galea, S., Gruber, M. J., Sampson, N. A., Ursano, R. J., & Wessely, S. (2008). Trends in mental illness and suicidality after Hurricane Katrina. *Molecular Psychiatry*, *13*(4), 374–384. https://doi.org/10.1038/sj.mp.4002119
56. Galea, S., Brewin, C. R., Gruber, M., Jones, R. T., King, D. W., King, L. A., McNally, R. J., Ursano, R. J., Petukhova, M., & Kessler, R. C. (2007). Exposure to hurricane-related stressors and mental illness after Hurricane Katrina. *Archives of General Psychiatry*, *64*(12), 1427. https://doi.org/10.1001/archpsyc.64.12.1427
57. DeWolfe, D. J., & Nordboe, D. (2000). *Training manual for mental health and human service workers in major disasters*. U.S. Dept. of Health and Human Services, Substance Abuse and Mental Health Services Administration, Center for Mental Health Services.
58. Hudson, J., Fielding, S., & Ramsay, C. R. (2019). Methodology and reporting characteristics of studies using interrupted time series design in Healthcare. *BMC Medical Research Methodology*, *19*(1). https://doi.org/10.1186/s12874-019-0777-x
59. Storch, E. A., Gregory, S., Salloum, A., & Quast, T. (2018). Psychopharmacology utilization among children with anxiety and obsessive–compulsive and related disorders following Hurricane Katrina. *Child Psychiatry & Human Development*, *49*(4), 632–642. https://doi.org/10.1007/s10578-017-0779-z
60. SAMHSA. (2019, August). *Disasters and people with serious mental illness*. Disaster Technical Assistance Center Supplemental Research Bulletin. Retrieved May 17, 2022, from https://www.samhsa.gov/sites/default/files/disasters-people-with-serious-mental-illness.pdf
61. Roberts, Y. H., Mitchell, M. J., Witman, M., & Taffaro, C. (2010). Mental health symptoms in youth affected by Hurricane Katrina. *Professional Psychology: Research and Practice*, *41*(1), 10–18. https://doi.org/10.1037/a0018339
62. Olteanu, A., Arnberger, R., Grant, R., Davis, C., Abramson, D., & Asola, J. (2011). Persistence of mental health needs among children affected by Hurricane Katrina in New Orleans. *Prehospital and Disaster Medicine*, *26*(1), 3–6. https://doi.org/10.1017/s1049023x10000099

Supplemental Figures

Substance use percent increase in the volume of crisis texts in the four months post-Ida.




Thoughts of suicide percent increase in the volume of crisis texts in the four months post-Ida.

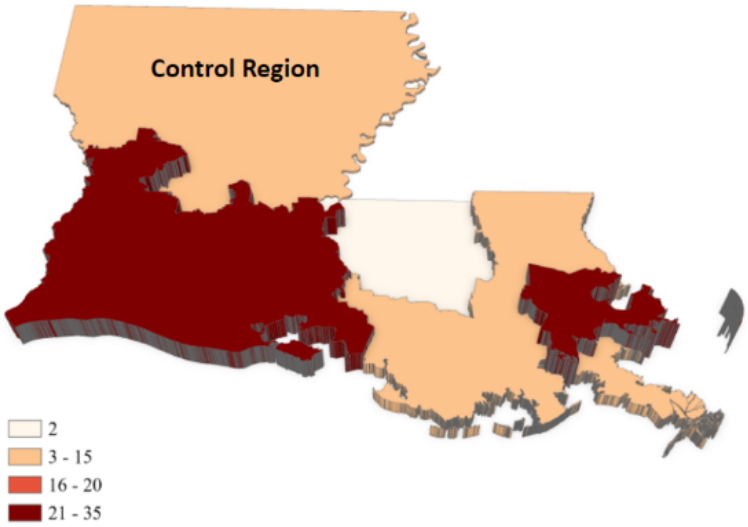


Figure depicts the parallel trend assumption with blue being the impacted group and red being the control group. The dividing line represents the date that Hurricane Ida made landfall (August 29, 2021).