# Supplemental Online Content

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This supplemental material has been provided by the authors to give readers additional information about their work.

**eAppendix.** Preliminary and exploratory analysis

A preliminary and exploratory analysis was conducted using an interrupted time series analysis approach to explore the population-level impacts and hazard period duration of the flooding and to inform the hazard period selection for the cohort analysis.

An ITSA using a Poisson regression was performed on a range of multi-week periods before and after flood onset across all flooded ZCTA. All-cause ED visits and HA, and certain cause-specific diagnoses for gastrointestinal illness (GI) and mental health (MH) conditions (Appendix 1, Table 1) were aggregated by week and used for the ITSA. The ITSA was performed using 2-, 4-, 6-, and 8-week periods before and after the flood to evaluate the temporal relationship between flood exposure and healthcare utilization. ZCTA-level flood data were used in the analysis, aggregated on a national level. A Poisson regression was used to estimate the relative risk (RR) and 95% confidence interval (CI) of a particular healthcare utilization type in the flood period compared to the pre-flood period.

ITSA model specification for weekly count of healthcare utilization events ($Y_T$):

$$Log(E(Y_T)) = \beta_0 + \beta_1 Time + \beta_2 Flood + \beta_3 TimeSinceFlood$$

where $\beta_0$ represents the baseline level of healthcare utilization, $\beta_1$ is the trend of healthcare utilization before the flood start, $\beta_2$ is the immediate change in the level of healthcare utilization at the start of the flood, and $\beta_3$ is the change in slope after the flood (interaction term).

The ITSA was performed on the 2-, 4-, 6-, and 8-week periods before and after flood start date and 16,536 flooded ZCTA were included in the analysis. The relative risk (RR) and 95% confidence intervals (CI) of healthcare utilization after flood onset, stratified by period duration in weeks, is shown in Appendix 1, Table 2. Across all durations of the ITSA, there was a statistically significant increase in risk of ED visits for all-cause and GI diagnoses of a similar magnitude across durations – for all-cause ED visits at 8 weeks, RR of 1.013 (95%CI: 1.009-1.018). No statistically significant association was seen with inpatient hospitalizations for all-cause or cause-specific diagnoses however, as noted in Appendix 1, Figure 1, the increase in ED visits was noted upon start of the flood while the RR of inpatient admissions demonstrated a trend towards significance during longer hazard period duration in weeks.

The ITSA revealed a statistically significant increase in the population-level risk of ED visits following flood exposure for all-cause, GI-specific, and mental health visits. The ED visit model predictions increased immediately after flood onset; while the model predictions were not statistically significant for hospitalizations, the model predictions demonstrated trends towards increased utilization up to 8 weeks after flood onset. The findings of the ITSA were used to inform the ZCTA-level analysis design of the cohort analysis. *A priori*, the control and hazard period length was 4-weeks in duration and this was supported by the ITSA. We considered using shorter periods, however had concerns about lag times to diagnosis, particularly for mental health conditions and those requiring hospitalization. While considering longer periods greater than 4-weeks, we had concerns about residual confounding and longer secular and seasonal trends and therefore limited the control and hazard periods to 4-weeks in the subsequent ZCTA-level cohort analysis.

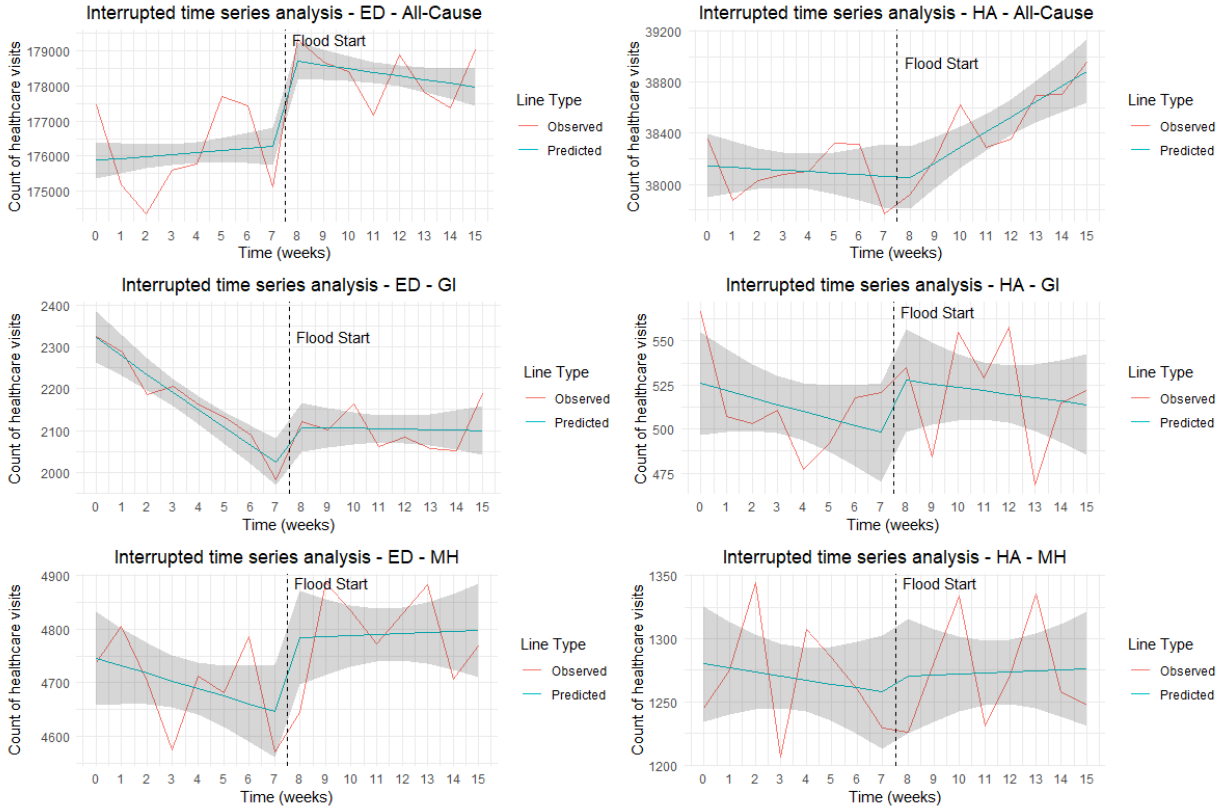
**Table 1**. 2015 Clinical Classifications Software (CCS) level 3 codes used for the identification of cause-specific outcomes for interrupted time series analysis (ITSA).

| *Category* | *CCS Code* | *Diagnosis* |
|---|---|---|
| Mental health (MH) | 650 | Adjustment disorders |
| | 651 | Anxiety disorders |
| | 657 | Mood disorders |
| | 659 | Schizophrenia and psychotic disorders |
| | 660 | Alcohol-related disorders |
| | 661 | Substance-related disorders |
| | 662 | Suicide and intentional self-injury |
| Gastrointestinal (GI) | 135 | Intestinal infection |
| | 144 | Enteritis and colitis |
| | 154 | Non-infectious gastroenteritis |

**Table 2.** Interrupted time series analysis (ITSA) regression all-cause and cause-specific relative risk (RR) and 95% confidence interval (CI) results by week and visit type, comparing pre- and post-flood period.

| *ITSA Duration* | *Encounter Type* | *RR* | *Lower 95% CI* | *Upper 95% CI* |
|---|---|---|---|---|
| 2-weeks | ED - All-Cause | 1.037 | 1.026 | 1.049 |
| | ED - GI | 1.120 | 1.009 | 1.245 |
| | ED - MH | 1.075 | 1.003 | 1.153 |
| | HA - All-Cause | 1.018 | 0.993 | 1.043 |
| | HA - GI | 0.982 | 0.799 | 1.211 |
| | HA - MH | 1.024 | 0.895 | 1.172 |
| 4-weeks | ED - All-Cause | 1.017 | 1.010 | 1.024 |
| | ED - GI | 1.091 | 1.025 | 1.162 |
| | ED - MH | 1.029 | 0.987 | 1.073 |
| | HA - All-Cause | 1.006 | 0.991 | 1.020 |
| | HA - GI | 0.947 | 0.836 | 1.074 |
| | HA - MH | 1.045 | 0.965 | 1.132 |
| 6-weeks | ED - All-Cause | 1.011 | 1.005 | 1.016 |
| | ED - GI | 1.071 | 1.020 | 1.126 |
| | ED - MH | 1.024 | 0.990 | 1.058 |
| | HA - All-Cause | 1.000 | 0.989 | 1.012 |
| | HA - GI | 1.027 | 0.929 | 1.135 |
| | HA - MH | 1.027 | 0.964 | 1.094 |
| 8-weeks | ED - All-Cause | 1.013 | 1.009 | 1.018 |
| | ED - GI | 1.065 | 1.021 | 1.112 |
| | ED - MH | 1.034 | 1.005 | 1.064 |
| | HA - All-Cause | 1.002 | 0.992 | 1.012 |
| | HA - GI | 1.062 | 0.974 | 1.157 |
| | HA - MH | 1.011 | 0.958 | 1.068 |

**Figure 1**. Interrupted time series analysis (ITSA) for select diagnoses in the 8-week period before and after flood start. Observed weekly diagnosis counts are shown in red, with ITSA model-predicted values in blue with 95% confidence intervals in grey.



**eTable 1**. 2015 Clinical Classifications Software (CCS) level 3 codes used for the identification of cause-specific outcomes for ZIP code tabulation area (ZCTA)-level cohort analysis

| *Category* | *CCS Codes* |
|---|---|
| Infectious and parasitic diseases (ID) | 1-10, 76-78, 90, 92, 122-126, 135, 144, 148, 159, 197, 201 |
| Metabolic, electrolytes, and renal (FEN) | 48-52, 55, 58, 156-157 |
| Cardiovascular and cerebrovascular (CV) | 96-113, 116-118, 245 |
| Respiratory (Resp) | 122-134 |
| Gastrointestinal (GI) | 135, 139-140, 142, 144-146, 148-149, 151-155, 250-251 |
| Orthopedic, external injury and poisoning (INJ) | 225-244, 2601-2621 |
| Mental health (MH) | 650-651, 657-663, 670 |

**eTable 2**. Frequency of ZIP code tabulation area (ZCTA) floods and median duration in the study period from the Muti-sourced Flood Inventories (MFI) by month

| *Month* | *Jan* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* | *Oct* | *Nov* | *Dec* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZCTA Floods | 476 | 180 | 1699 | 1694 | 3628 | 2436 | 362 | 1536 | 1813 | 920 | 112 | 1680 |
| Median Duration (days) | 3 | 22 | 16 | 5 | 40 | 29 | 4 | 9 | 8 | 9 | 9 | 10 |

**eTable 3**. Frequency of ZIP code tabulation area (ZCTA) floods and median duration in the study period from the Muti-sourced Flood Inventories (MFI) by year

| *Year* | *2008* | *2009* | *2010* | *2011* | *2012* | *2013* | *2014* | *2015* | *2016* | *2017* |
|---|---|---|---|---|---|---|---|---|---|---|
| ZCTA Floods | 2051 | 942 | 1837 | 3033 | 309 | 975 | 875 | 3108 | 1442 | 1964 |
| Median Duration (days) | 20 | 7 | 5 | 33 | 11 | 8 | 35 | 11 | 12 | 7 |

**eTable 4.** ZIP code tabulation area (ZCTA)-level regression stratified analysis all-cause incident rate ratio (IRR) and 95% confidence intervals (CI) by visit type and attributable risk percentage (AR%) and estimated attributable excess visits, comparing pre- and post-flood period

| *Encounter Type* | *Diagnosis Type* | *IRR* | *Lower 95% CI* | *Upper 95% CI* | *AR%* | *Visits in Flood Period* | *Excess Attributable Visits* |
|---|---|---|---|---|---|---|---|
| **Sex-stratified** | | | | | | | |
| Male | ED visits | 1.052 | 1.045 | 1.059 | 5.0% | 190,121 | 9,506 |
| | hospitalizations | 1.084 | 1.074 | 1.093 | 7.7% | 106,703 | 8,216 |
| Female | ED visits | 1.046 | 1.039 | 1.051 | 4.4% | 272,153 | 11,975 |
| | hospitalizations | 1.066 | 1.058 | 1.075 | 6.2% | 136,594 | 8,469 |
| **Age-stratified** | | | | | | | |
| 65-74 | ED visits | 1.03 | 1.023 | 1.037 | 2.9% | 193,252 | 5,604 |
| | hospitalizations | 1.049 | 1.039 | 1.059 | 4.7% | 99,060 | 4,656 |
| 75-84 | ED visits | 1.046 | 1.038 | 1.054 | 4.4% | 166,206 | 7,313 |
| | hospitalizations | 1.073 | 1.063 | 1.084 | 6.8% | 90,461 | 6,151 |
| 85+ | ED visits | 1.089 | 1.079 | 1.099 | 8.1% | 102,816 | 8,328 |
| | hospitalizations | 1.124 | 1.11 | 1.138 | 11.0% | 53,776 | 5,915 |
| **Race-stratified** | | | | | | | |
| White | ED visits | 1.047 | 1.042 | 1.052 | 4.50% | 399,640 | 17,984 |
| | hospitalizations | 1.074 | 1.067 | 1.081 | 6.80% | 214,567 | 14,591 |
| Black | ED visits | 1.054 | 1.039 | 1.068 | 5.10% | 46,851 | 2,389 |
| | hospitalizations | 1.084 | 1.061 | 1.106 | 7.70% | 20,984 | 1,616 |
| **Season-stratified** | | | | | | | |
| Winter | ED visits | 1.033 | 1.02 | 1.045 | 3.2% | 64,338 | 2,059 |
| | hospitalizations | 1.061 | 1.045 | 1.078 | 5.8% | 34,288 | 1,989 |
| Spring | ED visits | 1.039 | 1.032 | 1.046 | 3.8% | 175,027 | 6,651 |
| | hospitalizations | 1.048 | 1.038 | 1.058 | 4.6% | 92,562 | 4,258 |
| Summer | ED visits | 1.067 | 1.056 | 1.077 | 6.2% | 122,470 | 7,593 |
| | hospitalizations | 1.111 | 1.097 | 1.126 | 10.0% | 65,201 | 6,520 |
| Fall | ED visits | 1.049 | 1.038 | 1.06 | 4.7% | 100,439 | 4,721 |
| | hospitalizations | 1.085 | 1.071 | 1.099 | 7.8% | 51,246 | 3,997 |
| **Flood area-stratified** | | | | | | | |
| Quartile 1 | ED visits | 1.049 | 1.039 | 1.058 | 4.6% | 130,759 | 6,015 |
| | hospitalizations | 1.076 | 1.064 | 1.088 | 7.1% | 69,697 | 4,948 |
| Quartile 2 | ED visits | 1.065 | 1.056 | 1.074 | 6.1% | 139,959 | 8,537 |
| | hospitalizations | 1.084 | 1.07 | 1.098 | 7.7% | 67,665 | 5,210 |
| Quartile 3 | ED visits | 1.035 | 1.025 | 1.044 | 3.3% | 100,174 | 3,306 |
| | hospitalizations | 1.068 | 1.054 | 1.081 | 6.4% | 54,328 | 3,477 |
| Quartile 4 | ED visits | 1.037 | 1.027 | 1.047 | 3.6% | 91,382 | 3,290 |
| | hospitalizations | 1.063 | 1.05 | 1.076 | 5.9% | 51,607 | 3,045 |
| **SVI quartile-stratified** | | | | | | | |
| Quartile 1 | ED visits | 1.041 | 1.031 | 1.052 | 3.9% | 85,750 | 3,344 |
| | hospitalizations | 1.078 | 1.062 | 1.093 | 7.2% | 45,743 | 3,293 |
| Quartile 2 | ED visits | 1.044 | 1.035 | 1.054 | 4.2% | 121,893 | 5,120 |
| | hospitalizations | 1.075 | 1.063 | 1.087 | 7.0% | 64,730 | 4,531 |
| Quartile 3 | ED visits | 1.054 | 1.044 | 1.063 | 5.1% | 130,317 | 6,646 |
| | hospitalizations | 1.077 | 1.063 | 1.09 | 7.1% | 68,668 | 4,875 |
| Quartile 4 | ED visits | 1.048 | 1.038 | 1.058 | 4.6% | 124,314 | 5,718 |
| | hospitalizations | 1.066 | 1.053 | 1.079 | 6.2% | 64,156 | 3,978 |