Int J Biometeorol (2018) 62:685–697
DOI 10.1007/s00484-016-1265-1

SPECIAL ISSUE: LATIN AMERICA/CARIBBEAN

Where are weather-suicide associations valid? An examination of nine US counties with varying seasonality

P. Grady Dixon[1] · **Adam J. Kalkstein**[2]

Received: 29 July 2016 / Revised: 19 September 2016 / Accepted: 20 October 2016 / Published online: 7 November 2016

Abstract There has been much research on the associations between weather variables and suicide rates. However, the state of understanding has remained rather stagnant due to many contradictory findings. The purpose of this project is to examine a larger database of suicides that includes a longer and more recent period of record (1975–2010) across numerous locations in the USA. In all, we examine nine total counties (and the primary city associated with them) with a special effort made to compare locations with varying degrees of temperature seasonality: Cook (Chicago), Fulton (Atlanta), King (Seattle), Los Angeles (Los Angeles), Maricopa (Phoenix), Miami-Dade (Miami), Philadelphia (Philadelphia), Salt Lake (Salt Lake City), and St. Louis (St. Louis). We first examine the unique seasonal cycle in suicides evident in each locale and then use distributed lag nonlinear modeling (DLNM) to relate the suicide data to daily surface temperatures. Results suggest that a late spring/summer peak generally exists in suicide rates, and above average temperatures are associated with increased suicide risk in almost all study counties. Further, it appears that these associations can be found in both mid-latitude and sub-tropical climate types.

Keywords Suicide · Dlnm · Biometeorology · Climate

✉ P. Grady Dixon
pgdixon@fhsu.edu

[1] Department of Geosciences, Fort Hays State University, 600 Park St, Hays, KS, USA

[2] Department of Geography and Environmental Engineering, United States Military Academy, West Point, New York, USA

Introduction

Numerous studies have attempted to link environmental conditions with suicide rates, but results have been far from uniform. This lack of consistency is possibly a result of differing methodologies, variables, and geographic locations. The most common weather-suicide relationships appear to be with temperature, and recent studies have suggested a possible link between warmer weather and modest increases in suicide rates (Dixon et al. 2014; Hiltunen et al. 2014; Kim et al. 2016; Kim et al. 2011; Likhvar et al. 2011; Törő et al. 2009; Yang et al. 2011). While some previous research has resulted in the opposite conclusion suggesting that cold weather results in elevated suicides, only one such study has been published in the last several years (Tsai 2010). Some researchers have also concluded that other atmospheric variables such as solar radiation or air pollution may be related to changes in suicide as well (Holopainen et al. 2014; Ruuhela et al. 2009; Szyszkowicz et al. 2010; Vyssoki et al. 2012; Yang et al. 2011).

While the exact relationships are still poorly understood, it has become clear that most environment-health relationships involve lagged effects and nonlinear responses. For these reasons, recent environmental epidemiology research (Allen and Sheridan 2016; Burkart et al. 2014; Dixon et al. 2014; Gasparrini and Armstrong 2011; Gasparrini et al. 2010; Guo et al. 2011; Rocklov et al. 2012; Wang et al. 2014) has made use of the distributed lag nonlinear model (DLNM), which is a statistical package in R (Gasparrini 2011; http://cran.r-project.org/web/packages/dlnm).

DLNM is designed to estimate simultaneously the nonlinear and cumulative lag effects of exposure to an independent exposure variable (i.e., temperature, pollution, humidity, etc.) on mortality or morbidity. It is beneficial to allow simplified, flexible relationships that combine the exposure and lag

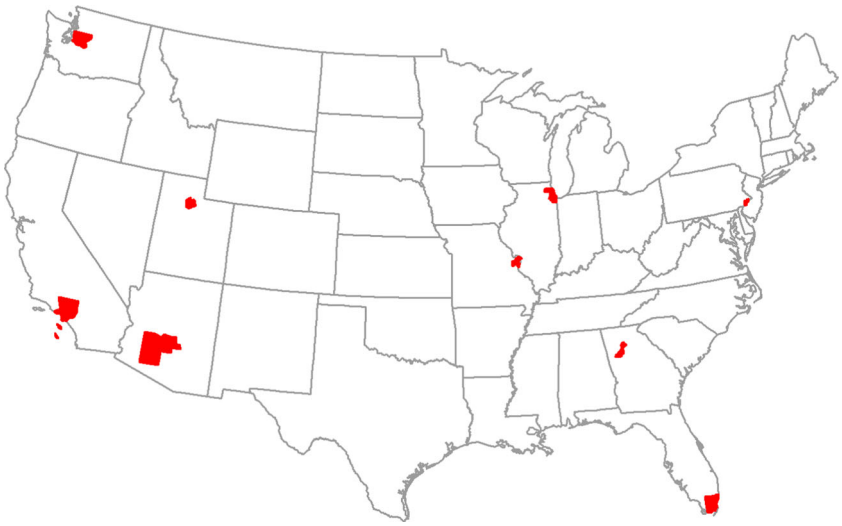

Fig. 1 Study counties

effects, and the "cross-basis" function of the DLNM allows the exposure and lag components to be separated and compared as well. In suicide research, there is no agreed-upon lag time between environmental exposure and response, so the flexibility of DLNM allows for cumulative effects of exposure and/or lag. Further, with DLNM, it is easy to normalize the data with respect to time at user-defined scales to control for periodic patterns (i.e., weekly or seasonal) and long-term trends. This is particularly important in suicide research, which consistently illustrates seasonality and trends associated with demographic changes, economic trends, intervention strategies, etc. (Dixon and Kalkstein 2009; Mok et al. 2012; Titelman et al. 2013; Watts et al. 2012).

Dixon et al. (2014) used DLNM to show a consistent association between increased suicide frequency and above-median temperatures for Toronto, Ontario, and Jackson, Mississippi. The purpose of this research is to expand that work to more locations to determine the consistency of this pattern. More specifically, it is important to apply the methods of Dixon et al. (2014) to a diverse selection of climate types to determine if the temperature-suicide associations are present across and beyond the mid-latitudes. A general lack of variability in many tropical climates has been suggested as a limiting factor in applying mid-latitude methods in applied climatology to tropical locations (Dixon et al. 2016). If the growing body of research on weather-suicide associations is to be used to help residents in and near the tropics, the methods must be tested on locations with demographics similar to previous studies but climates more similar to the tropics.

Data and methods

Study counties

For the purposes of this study, counties were chosen to represent a variety of climate types, with a particular focus on temperature seasonality. This required both arid and humid

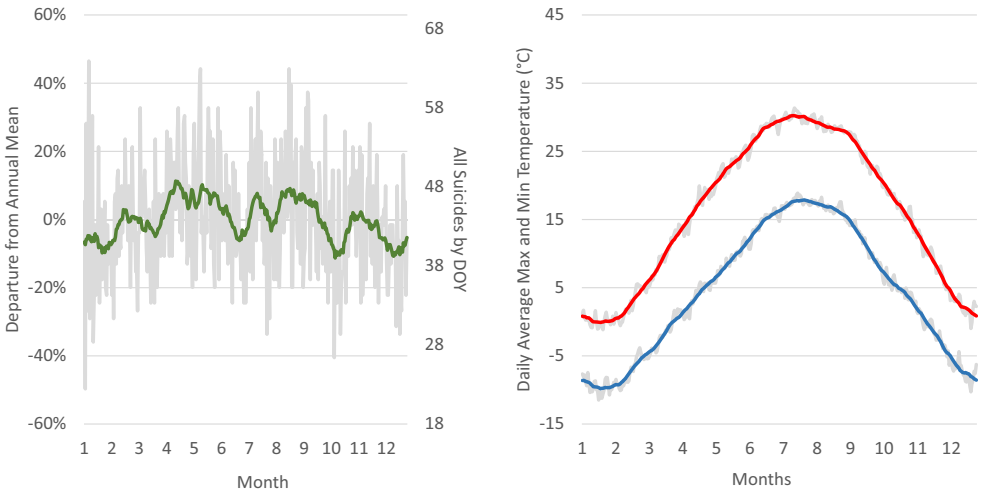

Fig. 2 For Cook County (Chicago), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

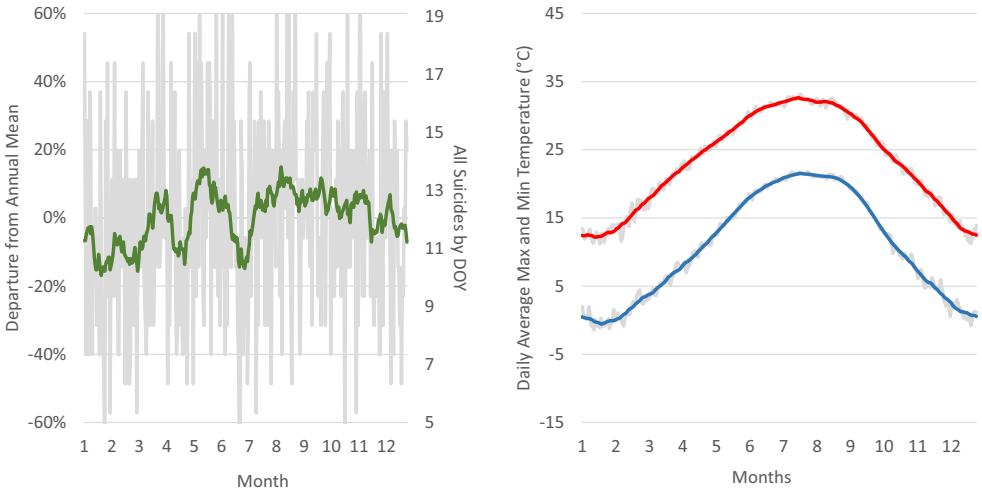

Fig. 3 For Fulton County (Atlanta), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

locations as well as northern and southern locations. Further, it was necessary that all counties had an adequately large sample size. There were some subjective decisions made during this process, but the chosen counties are as follows: Cook County (Chicago), Fulton County (Atlanta), King County (Seattle), Los Angeles County (Los Angeles), Maricopa County (Phoenix), Miami-Dade County (Miami), Philadelphia County (Philadelphia), St. Louis County (St. Louis), and Salt Lake County (Salt Lake City) (Fig. 1). This geographically, climatologically, and demographically diverse selection provides locations with both large temperature seasonality (Cook, St. Louis, and Salt Lake), moderate temperature seasonality (Fulton, Maricopa, and Philadelphia), and limited temperature seasonality (King, Miami-Dade, Los Angeles), as required to examine temperature-suicide relationships.

Suicide data

Daily suicide counts were obtained from the National Center for Health Statistics (NCHS). These data span 1975–2010 and are classified by the International Classification of Diseases, revisions 9 and 10 (ICD-9; ICD-10) based upon suicide and self-inflicted injury (ICD-9; E950-E959) along with intentional self-harm (ICD-10; X60-X84). Data were immediately aggregated into daily counts for each county, and individual cases were never examined.

Temperature data

Daily maximum and minimum temperature data were provided by the National Centers for Environmental Information (NCEI) and cover the years 1975–2010. These data were measured at each county's largest airport.

DLNM

Consistent with Dixon et al. (2014), we used the general linear model regression function to create estimations of daily suicide counts based on daily temperature

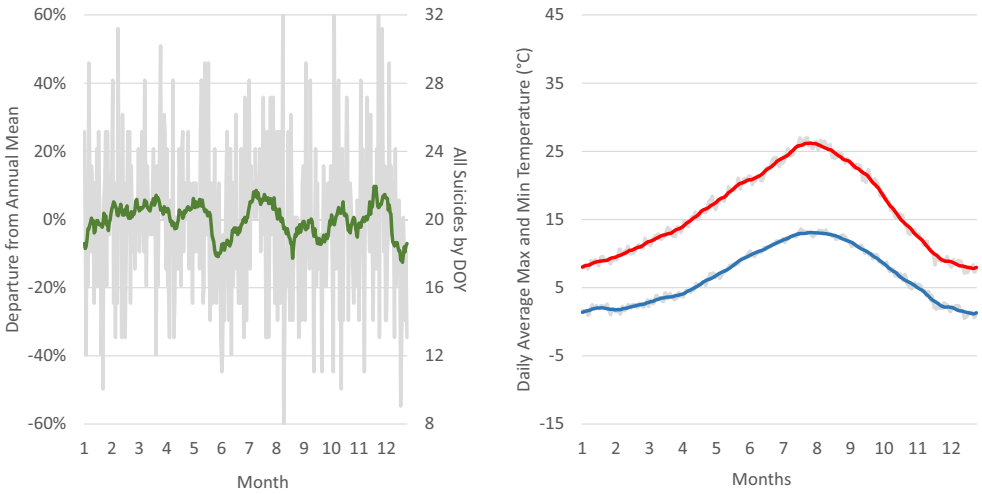

Fig. 4 For King County (Seattle), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; green represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

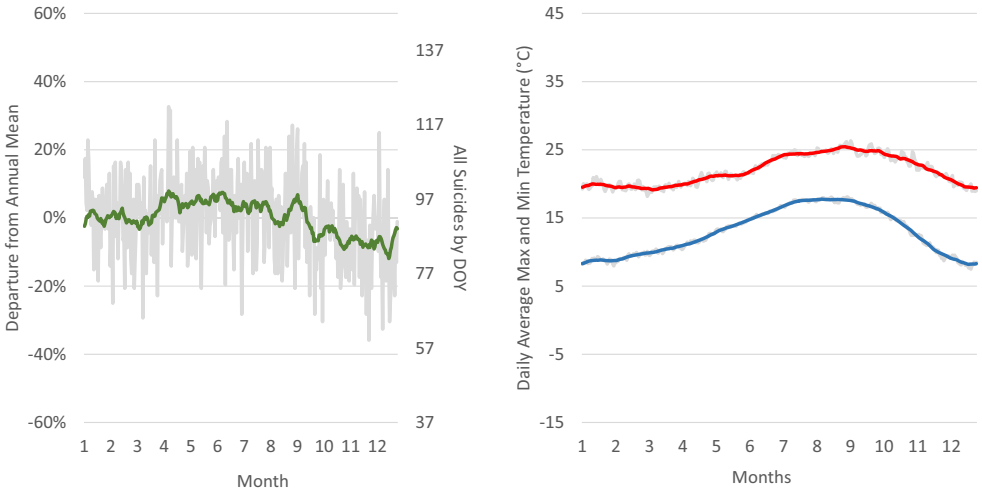

Fig. 5 For Los Angeles County (Los Angeles), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

values (maximum and minimum). Natural cubic splines allow for normalization with respect to various time scales. We compiled the model for only the annual scale, which requires 11 equally spaced spline knots. We also employed a categorical "day of week" spline to account for weekly cycles/patterns. Based on the best Akaike Information Criteria values reported by Dixon et al. (2014), a 6-day lag was used (equivalent to 1 week as "day 0" was the first exposure day), and splines for the response function as well as the lag polynomial function were allowed to have three and two degrees of freedom, respectively.

It is possible that meteorological variables have varying influences on suicide rates depending on the time of year, and as a result, DLNM was also used for "warm" and "cool" seasons, defined here as March through August and September through February, respectively. These two periods were selected based upon observed seasonal suicide rates discussed below, with the warm season generally experiencing elevated numbers of suicides.

Results

Suicide timing

For all study counties, suicide rates tend to peak during the warm season and/or reach a nadir during the cool season (Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10). Although the overall pattern is consistent with previous research, not all counties exhibited the same seasonal cycles. For example, while counties such as Los Angeles, Cook, and Maricopa all peak in the late spring or summer, Fulton peaks in the late summer and King exhibits little discernible seasonality other than sharp decreases in late May and late December.

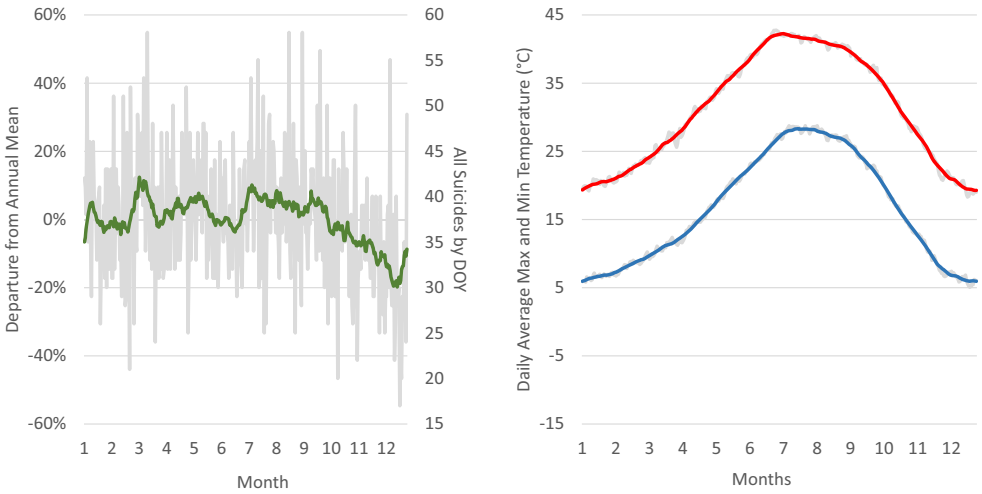

Fig. 6 For Maricopa County (Phoenix), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

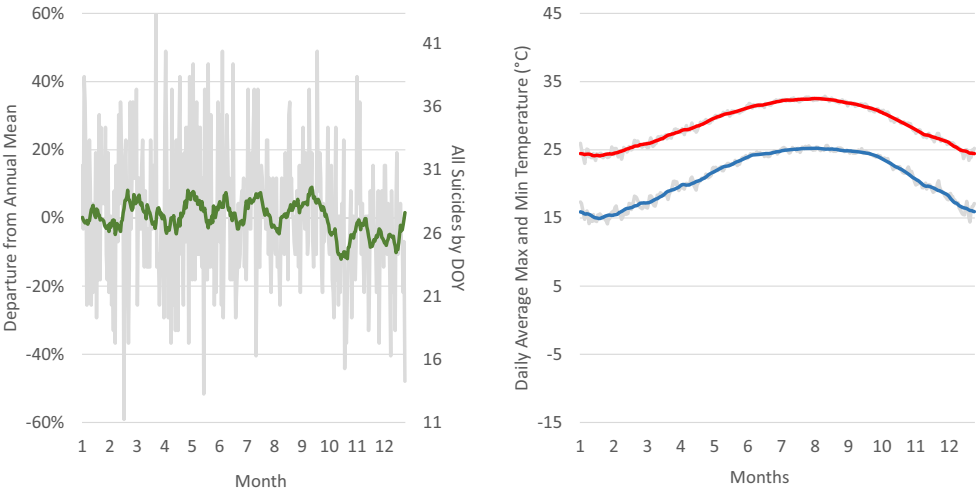

Fig. 7 For Miami-Dade County (Miami), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

Impact of weather

In general, it appears that anomalously warm conditions are associated with an elevated risk of suicide (Figs. 11, 12, 13, 14, 15, 16, 17, 18, 19), although this relationship varies somewhat by location and time of year. Figures 11–19 show the relative risk of suicide compared to the median temperature (illustrated by the minimum in gray-shaded confidence intervals) for the analysis period. Likewise, in most cases, below-median temperatures are associated with decreases in relative risk. The most consistent relationships are found in Cook County (Fig. 11), Los Angeles County (Fig. 14), and Maricopa County (Fig. 15), all of which generally display increases in relative risk associated with above-median temperatures throughout the year. In Cook County, relative risk of suicide increases markedly with higher temperatures, particularly in the cold season. Results are similar in Los Angeles, where weather-suicide relationships are strongest in the cold season, while in Maricopa, strong weather-suicide relationships exist year-round.

Among the other counties, both Miami-Dade (Fig. 16) and Philadelphia (Fig. 17) display consistent temperature-suicide relationships, and above-median temperatures are associated with higher relative risk of suicide throughout the year. However, these relationships are not quite as strong as Cook, Los Angeles, and Maricopa. King County (Fig. 13) and Salt Lake County (Fig. 19) display very modest temperature-suicide relationships only in the cold season while Fulton (Fig. 12) and St. Louis (Fig. 18) have positive temperature-suicide relationships only in the warm season with negative relationships occurring during the rest of the year.

Discussion

This research provides strong evidence that above-median temperatures, both in warm and cold seasons and across

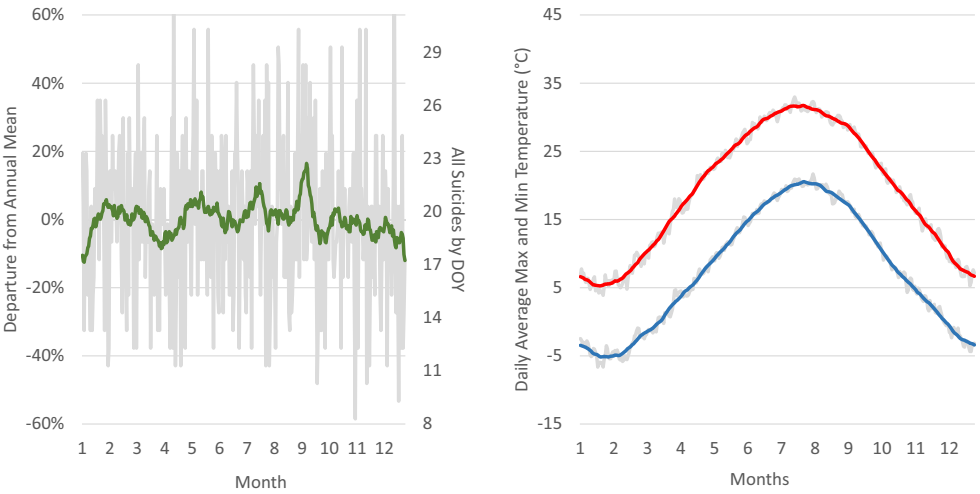

Fig. 8 For Philadelphia County (Philadelphia), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

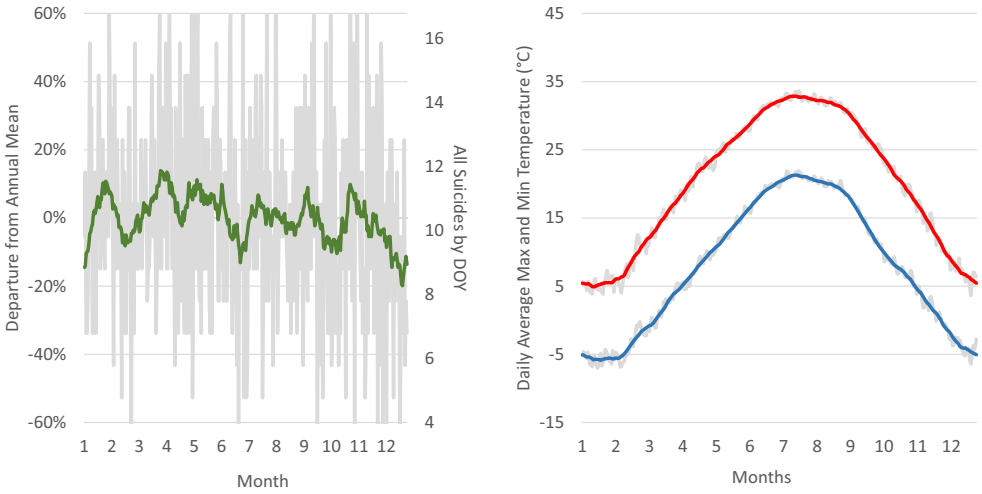

Fig. 9 For St. Louis County (St. Louis), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (right panel) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

numerous locales, are associated with an elevated risk of suicide. Likewise, below-median temperatures are often associated with a decreased risk of suicide. With a few notable exceptions, results are relatively consistent across the nine counties examined, although it appears that sample size plays a large role. The most populous counties exhibit the strongest weather-suicide signals while the smallest populations generally exhibit weaker or less-consistent relationships.

In addition to the weather-suicide associations, this research adds to the growing literature highlighting a seasonality to suicides in the mid-latitudes and possibly the sub-tropics. Consistent with previous research, suicides tend to peak in the late spring and summer, although once again, sample size is a factor with the largest populations displaying the most pronounced and most consistent seasonality. One of the motivations for this study, and the selection of counties, was to assess the suicide seasonality in locations with and without strong seasonality in temperatures. It was hypothesized that less-seasonal climates in Los Angeles and Miami and the consistently warm desert of Phoenix might display less suicide seasonality than other locations. Further, there was a question regarding how a less-seasonal pattern in suicide totals might affect the relationship between anomalously warm temperatures and increased suicide rates highlighted by Dixon et al. (2014). The results show that neither concern is valid as some of the locations with the least amount of annual variation in temperature display some of the greatest suicide seasonality and weather-suicide associations. Miami, which has a climate that is more tropical than the other locations of this study, shows some moderate seasonality in suicides with a decrease late in the year. More importantly, data from Miami show weather-suicide associations consistent with other locations with above-median temperatures associated with increased suicide rates. This suggests that while the temperature-suicide relationship may not hold up across the globe, it is unlikely to be limited to mid-latitude, seasonal climate types.

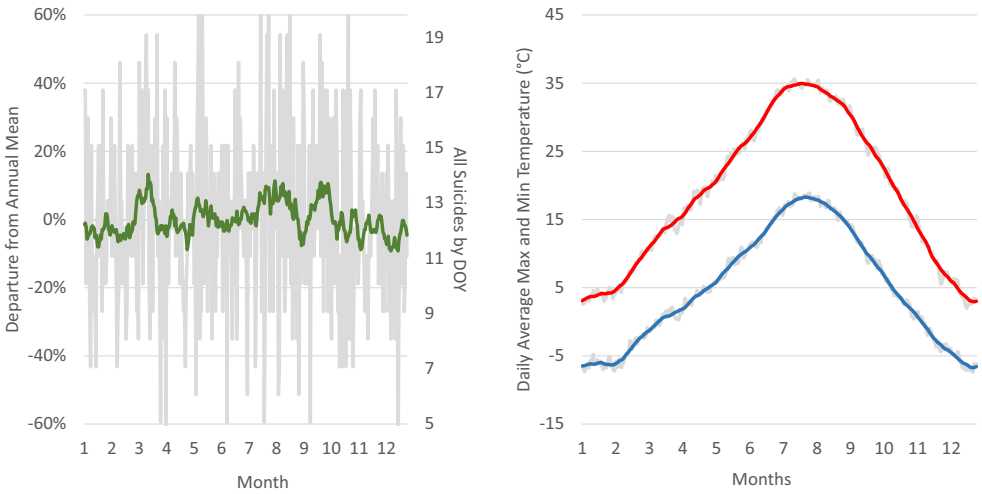

Fig. 10 For Salt Lake County (Salt Lake City), suicide seasonality (*left panel*) is illustrated by suicide totals by day of year (*right axis*; *green* represents a 21-day moving average) and the percent departure from annual mean (*left axis*). Temperature seasonality (*right panel*) is illustrated by daily average maximum (*red* represents a 21-day moving average) and minimum (*blue* represents a 21-day moving average) temperatures

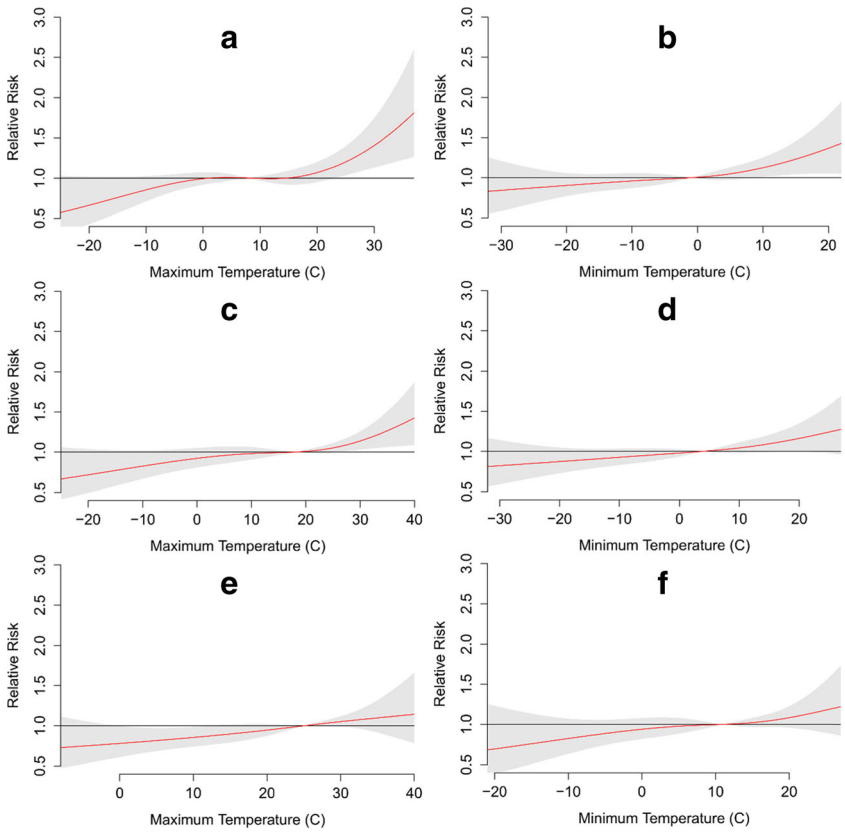

Fig. 11 Cook County (Chicago) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

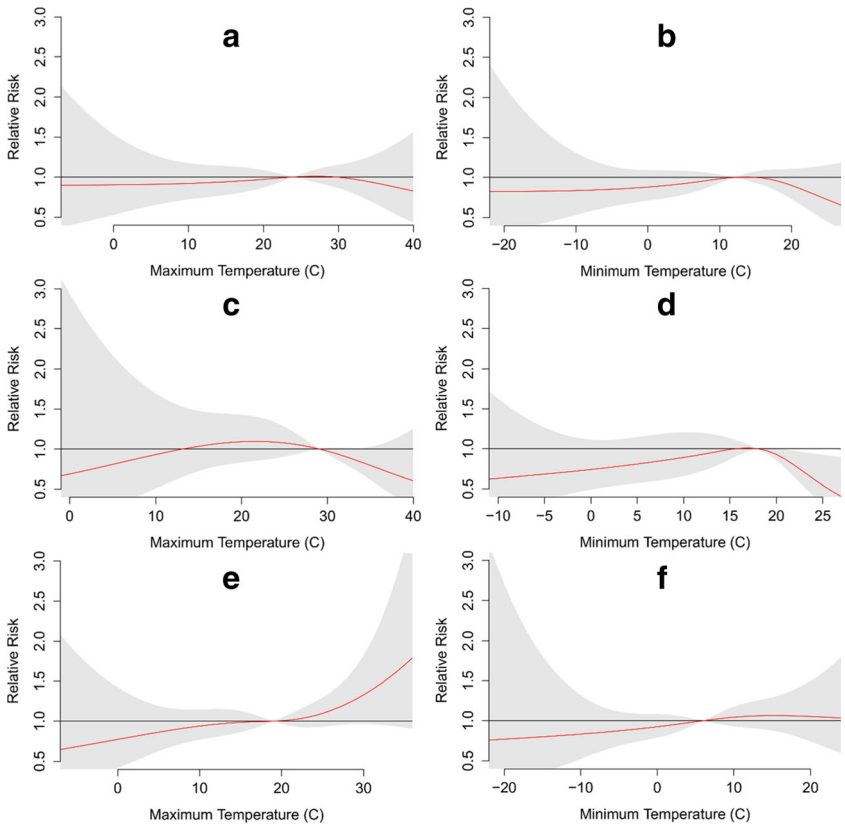

Fig. 12 Fulton County (Atlanta) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

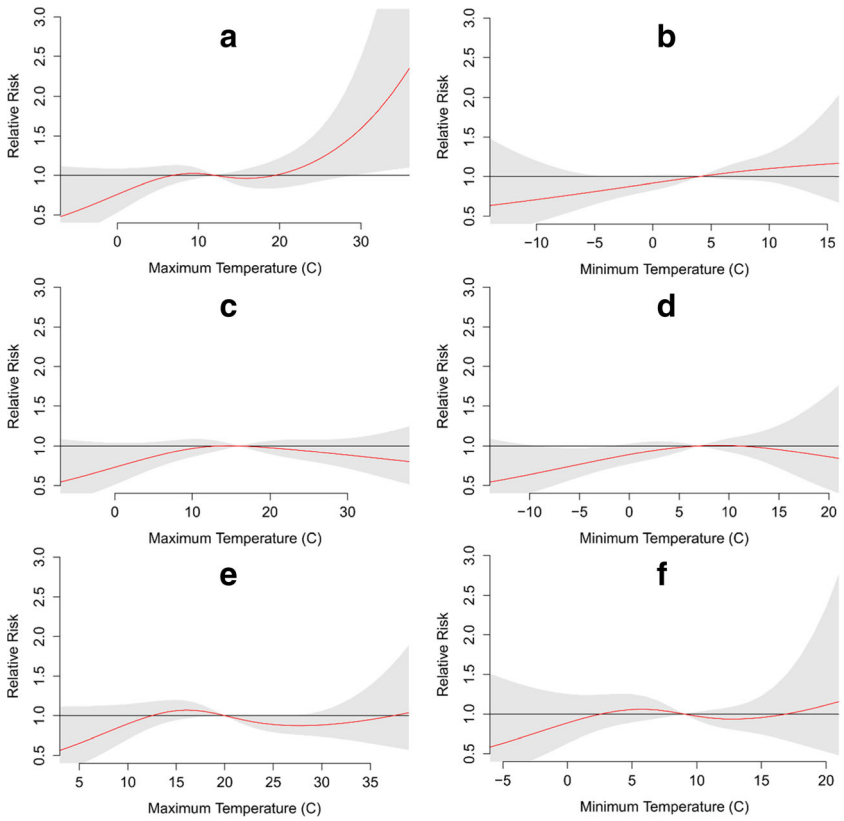

Fig. 13 King County (Seattle) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

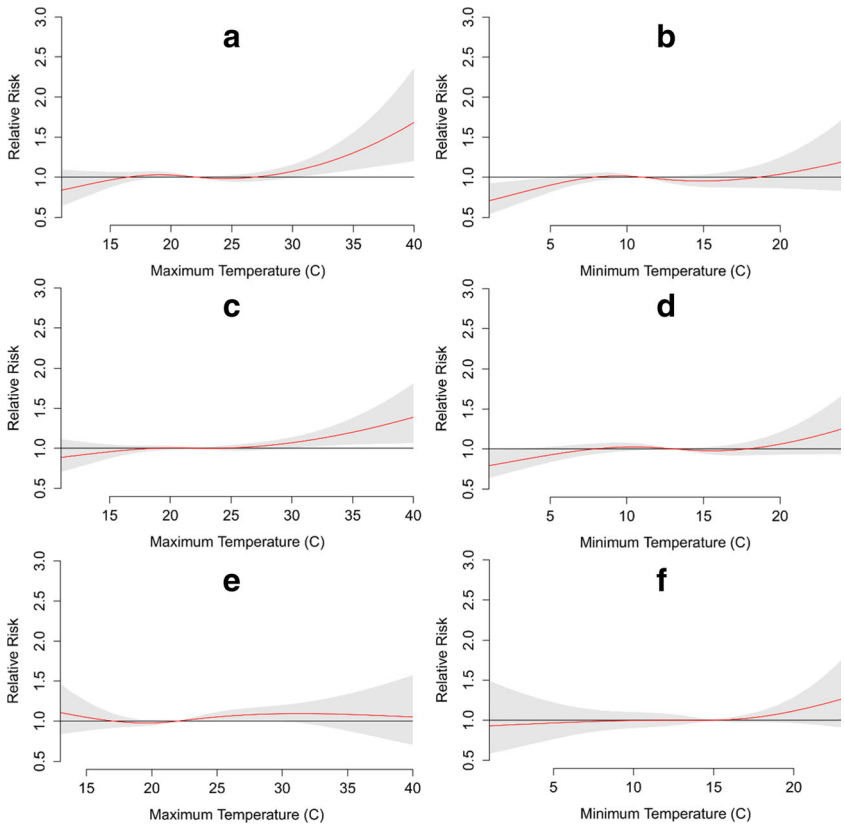

Fig. 14 Los Angeles County (Los Angeles) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

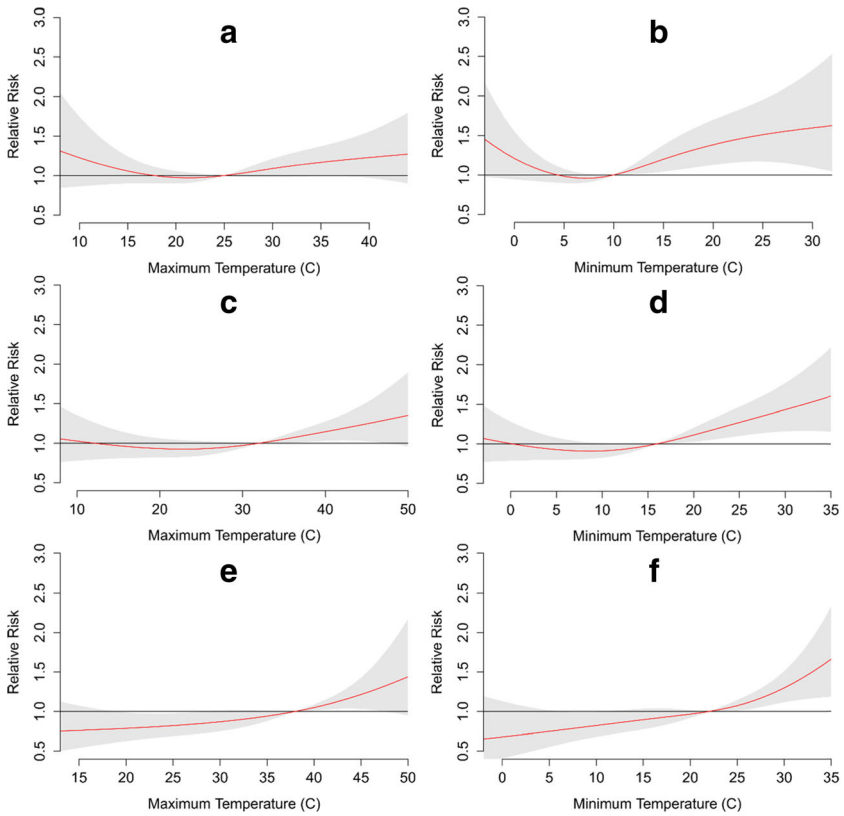

Fig. 15 Maricopa County (Phoenix) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

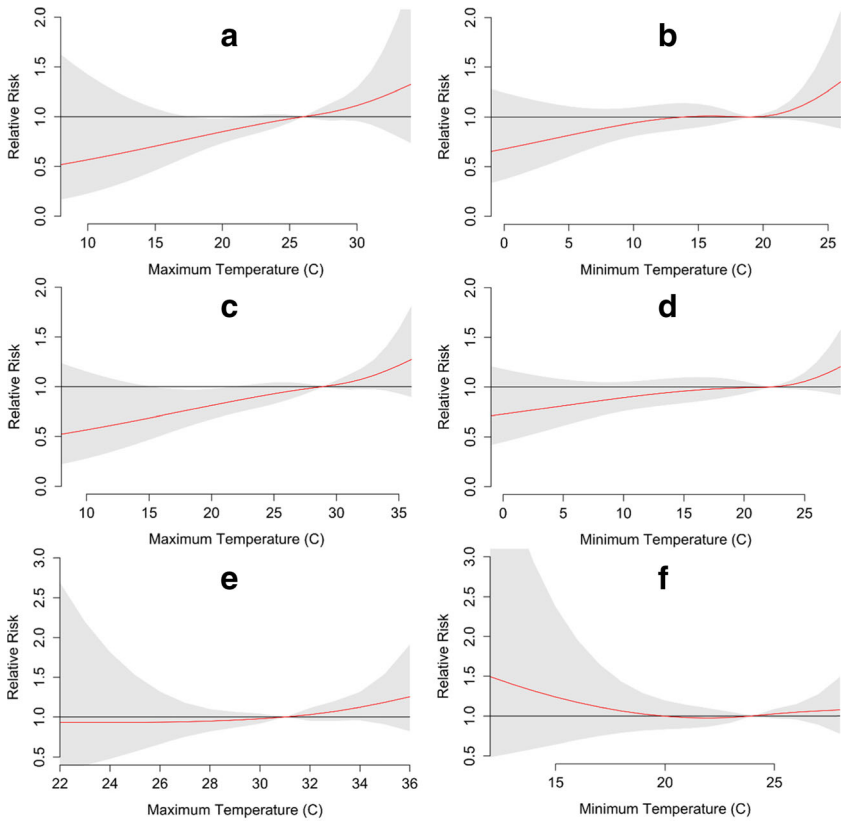

Fig. 16 Miami-Dade County (Miami) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

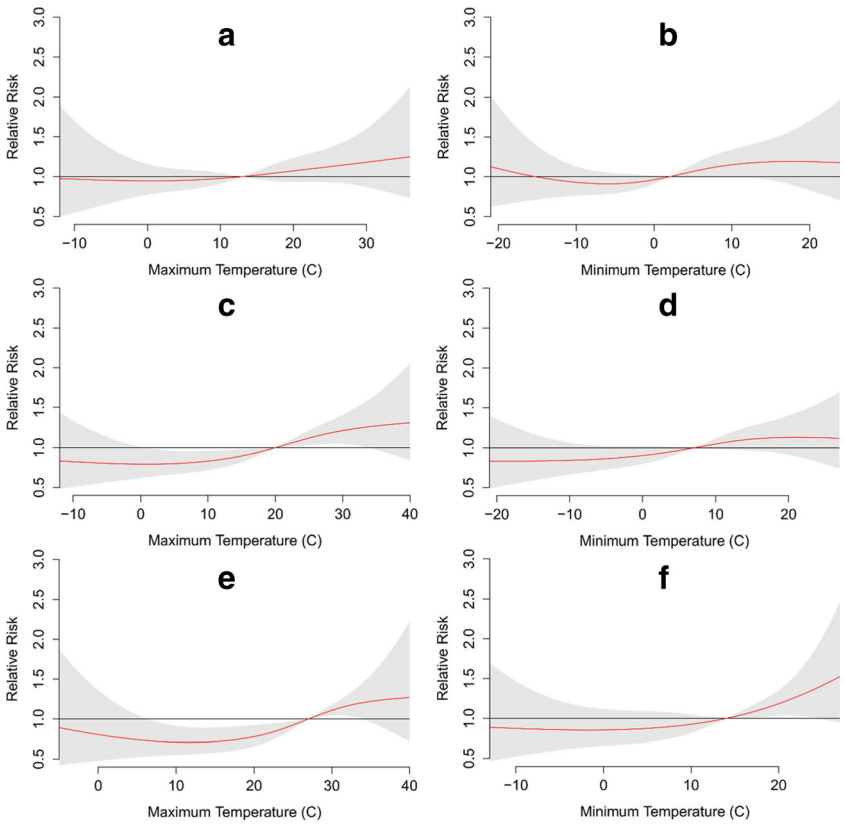

Fig. 17 Philadelphia County (Philadelphia) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

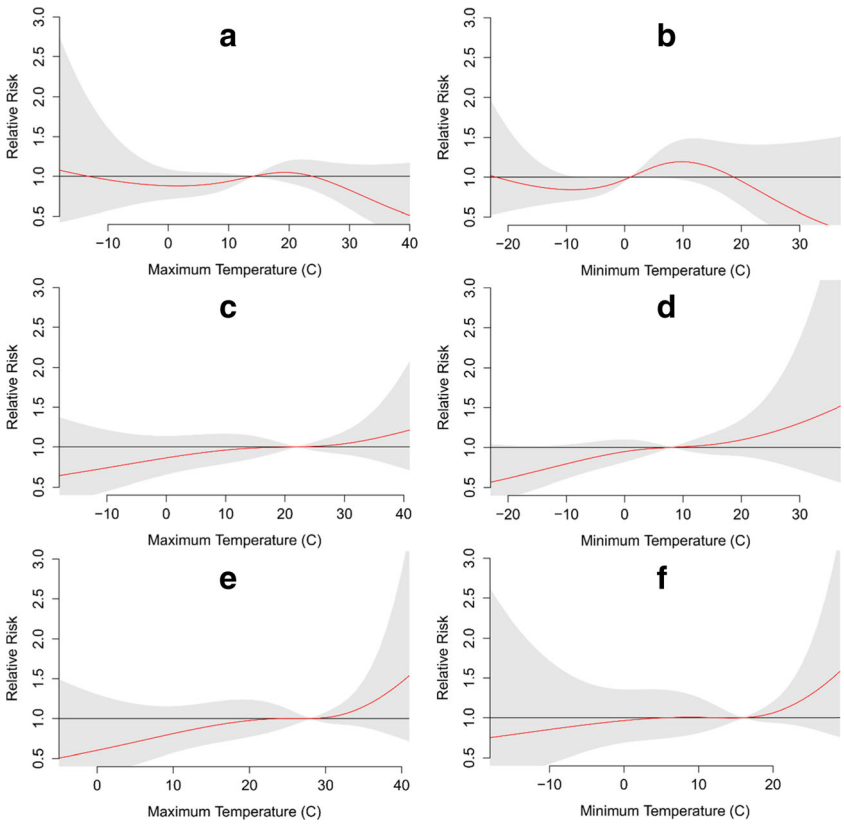

Fig. 18 St. Louis County (St. Louis) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

Connections between seasonality and weather-suicide associations

Among the three counties (Cook, Los Angeles, and Maricopa) identified above as having the most consistent increases in suicides with anomalously warm temperatures, three very different climate types are represented. Cook experiences strong seasonality in temperatures and a clear maximum suicide rate during the warm season (Fig. 2). Los Angeles experiences the smallest annual temperature variations, but displays a clear seasonality in suicide rates with more occurring April–August than October–February (Fig. 5). Maricopa's desert climate displays a moderate annual temperature range that rarely reaches freezing, and its suicide rates display some seasonality with relatively consistent values during the warm season followed by a steady decrease during September–December (Fig. 6). This suggests that temperature seasonality is not an indicator or requirement for weather-suicide associations. Miami-Dade County displays seasonality patterns (temperature and suicide rates) that are similar to Los Angeles, and results also suggest a consistent pattern of increased suicides during above-median temperatures throughout the year.

Most states in the USA have shown a decrease in suicide seasonality since 1975 (Dixon and Kalkstein 2014), so it is not surprising to see a weakened pattern in some locations. However, it is unexpected to see such a strong decline in suicides in late spring or early summer (Fig. 4). This is inconsistent with the pattern displayed by the state of Washington (Dixon and Kalkstein 2014), so more research is warranted, especially since similar brief, warm-season declines are seen for Cook (Fig. 2), Fulton (Fig. 3), and St. Louis (Fig. 9) Counties.

Potential underlying causes of suicide seasonality

Numerous research studies have attempted to isolate the specific causal mechanisms responsible for increased suicide rates in the late spring and early summer. Although results vary considerably, they generally fall within two categories: physiological changes in the human body and/or culture. Petridou et al. (2002) suggest that increased sunshine during the late spring and early summer can impact melatonin along with other hormones affected by light, which can in turn lead to increased rates of suicide. Similarly, psychiatric and affective disorders, especially those closely associated with suicide, tend to peak at a similar time of year, possibly caused by seasonal changes in hormones, serotonin, or other neuro-transmitters (Reutfors et al. 2009; Rocchi et al. 2007). Despite these observed seasonal changes in the human body, other studies conclude that culture

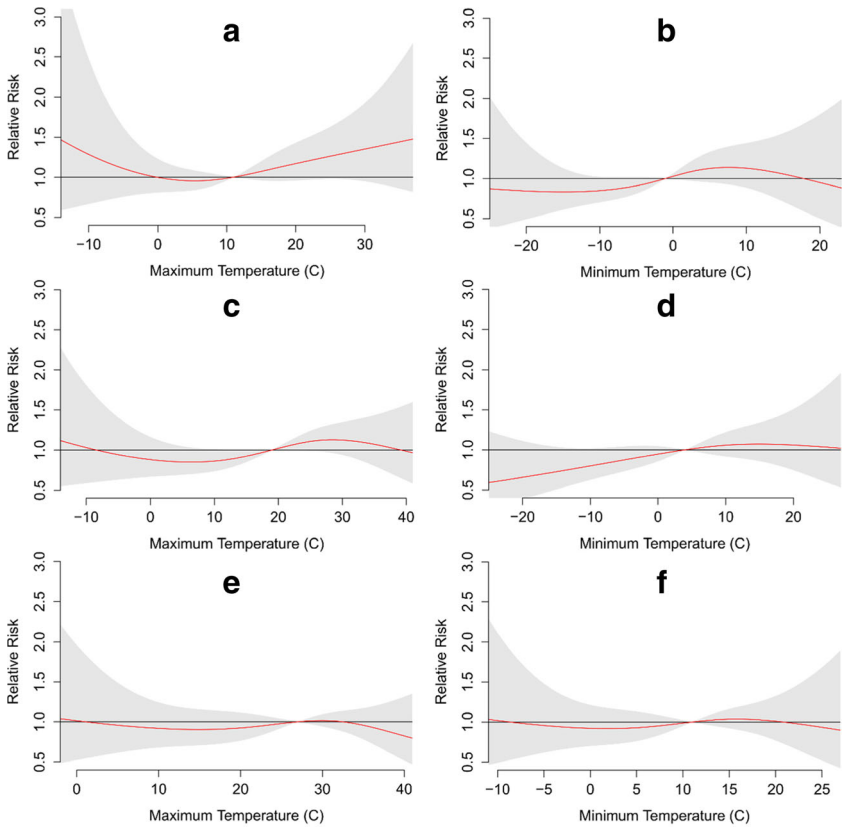

Fig. 19 Salt Lake County (Salt Lake City) relative risk for suicide, compared to median temperature for the period, with respect to **a** maximum daily temperature during the cool season, **b** minimum daily temperature during the cool season, **c** maximum daily temperature annually, **d** minimum daily temperature annually, **e** maximum daily temperature during the warm season, **f** and minimum daily temperature during the warm season

plays a larger role in the timing of the late spring and early summer peak in suicide rates. For example, Sun et al. (2011) suggest that increased stress from the upcoming school year might play a role. Alternatively, in more rural locales, stress from the approaching harvest season or even an increased accessibility to potentially harmful resources such as chemicals or tools might be partially responsible. Other researchers reach similar conclusions and note that cultural changes and even fluctuations in anti-depressant use can potentially explain higher incidences of suicide in the middle of the year (Ajdacic-Gross et al. 2005; Rock et al. 2003).

Conclusions

This research shows that weather-suicide associations, specifically increased suicides with anomalously warm conditions, occur similarly across numerous climate types within the USA. Ultimately, an important goal of this research is to work towards a predictive model, and with additional research, it may be possible to predict periods of elevated suicide rates in advance, perhaps allowing for preventative measures to be taken. Future research will examine additional locales to determine if similar temperature-suicide relationships exist across other regions of the USA. Further, demographic information can be used to determine if certain subsets of the population (i.e., male or female) are disproportionately affected by elevated temperatures. Additionally, the method of suicide (violent versus non-violent) can also be examined. Unfortunately, as seen in this study, larger populations with greater suicide totals tend to provide the most robust results. This means that the options for studying more locations are limited, and division into population subsets creates further challenges with sample sizes. At the very least, this research helps fill a gap in the scientific literature and provides additional evidence that risk of suicide increases under unusually warm conditions.

When combined with other recent research (Dixon et al. 2014; Hiltunen et al. 2014; Kim et al. 2016; Kim et al. 2011; Likhvar et al. 2011; Törő et al. 2009; Yang et al. 2011), the results of this study show that periods of anomalously high temperatures tend to increase suicides, during at least part of the year, in multiple locations around the world, including at least 10 cities in the USA and locations in Canada, Finland, Japan, Korea, and Taiwan. Almost all of the studied locations are in the mid-latitudes, but Taiwan is tropical to sub-tropical, and its climate is comparable to Miami. This research should be expanded to large populations around the world, but tropical locations should be a priority due to a lack of previous research despite some tropical countries (Guyana, Suriname, India, Sri Lanka, and several African countries) displaying suicide rates among the highest in the world (WHO 2016).

References

Ajdacic-Gross V et al (2005) Diversity and change in suicide seasonality over 125 years. J Epidemiol Community Health 59:967–972

Allen MJ, Sheridan SC (2016) Mortality risks during extreme temperature events (ETEs) using a distributed lag non-linear model. Int J Biometeorol. doi:10.1007/s00484-015-1117-4

Burkart K, Breitner S, Schneider A, Khan MM, Krämer A, Endlicher W (2014) An analysis of heat effects in different subpopulations of Bangladesh. Int J Biometeorol 58:227–237. doi:10.1007/s00484-013-0668-5

Dixon PG, Kalkstein AJ (2009) Climate-suicide relationships: a research problem in need of geographic methods and cross-disciplinary perspectives. Geography Compass 3:1961–1974. doi:10.1111/j.1749-8198.2009.00286.x

Dixon PG, Kalkstein AJ (2014) Suicide seasonality in the United States. Paper presented at the 2014 Annual Meeting of the Association of American Geographers, Tampa, Florida

Dixon PG, Sinyor M, Schaffer A, Levitt A, Haney CR, Ellis KN, Sheridan SC (2014) Association of weekly suicide rates with temperature anomalies in two different climate types. Int J Environ Res Public Health 11:11627–11644

Dixon PG, Allen M, Gosling SN, Hondula DM, Ingole V, Lucas R, Vanos J (2016) Perspectives on the synoptic climate classification and its role in interdisciplinary research. Geography Compass 10:147–164. doi:10.1111/gec3.12264

Gasparrini A (2011) Distributed lag linear and non-linear models in R: the package dlnm. J Stat Softw 43:1

Gasparrini A, Armstrong B (2011) The impact of heat waves on mortality. Epidemiology 22:68–73 (Cambridge, Mass)

Gasparrini A, Armstrong B, Kenward M (2010) Distributed lag non-linear models. Stat Med 29:2224–2234

Guo Y, Barnett AG, Pan X, Yu W, Tong S (2011) The impact of temperature on mortality in Tianjin, China: a case–crossover design with a distributed lag non-linear model. Environ Health Perspect 119:1719–25

Hiltunen L, Haukka J, Ruuhela R, Suominen K, Partonen T (2014) Local daily temperatures, thermal seasons, and suicide rates in Finland from 1974 to 2010. Environ Health Prev Med 19:286–294. doi:10.1007/s12199-014-0391-9

Holopainen J, Helama S, Partonen T (2014) Does diurnal temperature range influence seasonal suicide mortality? Assessment of daily data of the Helsinki metropolitan area from 1973 to 2010. Int J Biometeorol. doi:10.1007/s00484-013-0689-0

Kim Y, Kim H, Kim D-S (2011) Association between daily environmental temperature and suicide mortality in Korea (2001–2005). Psychiatry Res 186:390–396

Kim Y, Kim H, Honda Y, Guo YL, Chen B-Y, Woo J-M, Ebi KL (2016) Suicide and ambient temperature in East Asian countries: a time-stratified case-crossover analysis. Environ Health Perspect 124:75–80. doi:10.1289/ehp.1409392

Likhvar V, Honda Y, Ono M (2011) Relation between temperature and suicide mortality in Japan in the presence of other confounding factors using time-series analysis with a semiparametric approach. Environ Health Prev Med 16:36–43

Mok PLH, Kapur N, Windfuhr K, Leyland AH, Appleby L, Platt S, Webb RT (2012) Trends in national suicide rates for Scotland and for England & Wales, 1960–2008. Br J Psychiatry 200:245–251. doi:10.1192/bjp.bp.111.092908

Petridou E, Papadopoulos FC, Frangakis CE, Skalkidou A (2002) A role of sunshine in the triggering of suicide. Epidemiology 13:106–109

Reutfors J, Ösby U, Ekbom A, Nordström P, Jokinen J, Papadopoulos FC (2009) Seasonality of suicide in Sweden: relationship with psychiatric disorder. J Affect Disord 119:59–65

Rocchi MBL, Sisti D, Cascio MT, Preti A (2007) Seasonality and suicide in Italy: amplitude is positively related to suicide rates. J Affect Disord 100:129–136

Rock D, Greenberg DM, Hallmayer JF (2003) Increasing seasonality of suicide in Australia 1970-1999. Psychiatry Res 120:43–51

Rocklov J, Barnett AG, Woodward A (2012) On the estimation of heat-intensity and heat-duration effects in time series models of temperature-related mortality in Stockholm, Sweden. Environ Health. 11

Ruuhela R, Hiltunen L, Venäläinen A, Pirinen P, Partonen T (2009) Climate impact on suicide rates in Finland from 1971 to 2003. Int J Biometeorol 53:167–175

Sun J, Guo X, Ma J, Zhang J, Jia C, Xu A (2011) Seasonality of suicide in Shandong China, 1991–2009: associations with gender, age, area and methods of suicide. J Affect Disord 135:258–266

Szyszkowicz M, Willey JB, Grafstein E, Rowe BH, Colman I (2010) Air pollution and emergency department visits for suicide attempts in Vancouver, Canada. Environmental Health Insights 4:79–86

Titelman D et al (2013) Suicide mortality trends in the Nordic countries 1980–2009. Nordic Journal of Psychiatry 67:414–423. doi:10.3109/08039488.2012.752036

Törő K, Dunay G, Bartholy J, Pongrácz R, Kis Z, Keller É (2009) Relationship between suicidal cases and meteorological conditions. J Forensic Legal Med 16:277–279

Tsai J-F (2010) Socioeconomic factors outweigh climate in the regional difference of suicide death rate in Taiwan. Psychiatry Res 179:212–216

Vyssoki B, Praschak-Rieder N, Sonneck G, Blüml V, Willeit M, Kasper S, Kapusta ND (2012) Effects of sunshine on suicide rates. Compr Psychiatry 53:535–539

Wang X, Lavigne E, Ouellette-kuntz H, Chen BE (2014) Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. J Affect Disord 155:154–161. doi:10.1016/j.jad.2013.10.042

Watts BV, Young-Xu Y, Mills PD, DeRosier JM, Kemp J, Shiner B, Duncan WE (2012) Examination of the effectiveness of the mental health environment of care checklist in reducing suicide on inpatient mental health units. Arch Gen Psychiatry 69:588–592. doi:10.1001/archgenpsychiatry.2011.1514

WHO (2016) World Health Statistics 2016 vol 2016. World Health Organization, Geneva

Yang AC, Tsai S-J, Huang NE (2011) Decomposing the association of completed suicide with air pollution, weather, and unemployment data at different time scales. J Affect Disord 129:275–281