Title: **Temperature and Well-Being in the US: The Sub-Clinical Implications of Global Warming**

Paper for PAA Meeting in San Diego, 2015

Authors: Clemens Noelke[1], Daniel Corsi[2], Mark McGovern[1], Marcia Pescador-Jimenez[3], Ari Stern[4], Ian Sue Wing[4], Lisa Berkman[1]

Affiliations:

1. Center for Population and Development Studies, Harvard School of Public Health, Cambridge, MA
2. Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, Canada
3. School of Public Health, Brown University, Providence, RI
4. Department of Earth and Environment, Boston University, Boston, MA

Word count: 2,851

Address for correspondence

Clemens Noelke
Center for Population and Development Studies
9 Bow Street
Cambridge, MA 02138
Email: cnoelke@hsph.harvard.edu

ABSTRACT

This study uses data on nearly 1.9 Million Americans to quantify the impact of short-term temperature variation on a comprehensive measure of emotional well-being. Our data include daily well-being indicators, e.g., feelings of happiness, anger or stress, for approximately 1000 respondents aged 18+ over the period from 2008 to 2013. We identify non-linear temperature effects from temperature variation within Zipcode Tabulation Areas. We find robust evidence that temperature above 70°F causes statistically significant reductions in emotional well-being, with temperature in excess of 90°F resulting in a well-being loss of 5% of a standard deviation. In contrast, temperatures below 20°F increase well-being. Temperature effects at both ends of the distribution are driven by feelings of stress and tiredness, which increase at hot temperatures and diminish at cold temperatures. Using information on future climate conditions, we provide initial evidence that global warming will reduce emotional well-being across the contiguous US.

INTRODUCTION

The 20th century has witnessed remarkable adaptation to hot temperatures. Electrification, the spread of air conditioning, weather forecasting, increased public awareness of and improved community level-responses to heat waves have protected large segments of the U.S. population from the most hazardous health effects of extreme heat.(1–4) In consequence, the effect of hot temperatures on mortality has declined substantially in the course of the 20th century.(1) It is unclear, however, whether heat and global warming affect less extreme outcomes such as mental health, emotional well-being and happiness.(5) The risk of being exposed to hazardous temperature conditions increases with global warming, which should negatively affect well-being.(2) Moreover, heat indirectly reduces well-being by increasing monetary and time costs of adaptation, e.g., air conditioning expenditures and changes to daily routines.(2, 6)

Adaptation has been and likely will be the default strategy for individuals and societies to deal with weather extremes and climate change. Individuals make investments (e.g. buy an air conditioner) and alter their behavior (e.g. substitute time spent inside for time spent outside) to minimize discomfort or health risks due to heat.(5, 6) While adaptation has reduced the effect of heat on mortality over the course of the 20th century,(1) global warming will challenge the adaptive capacity of the US population in ways that we hypothesize will lower individual well-being.

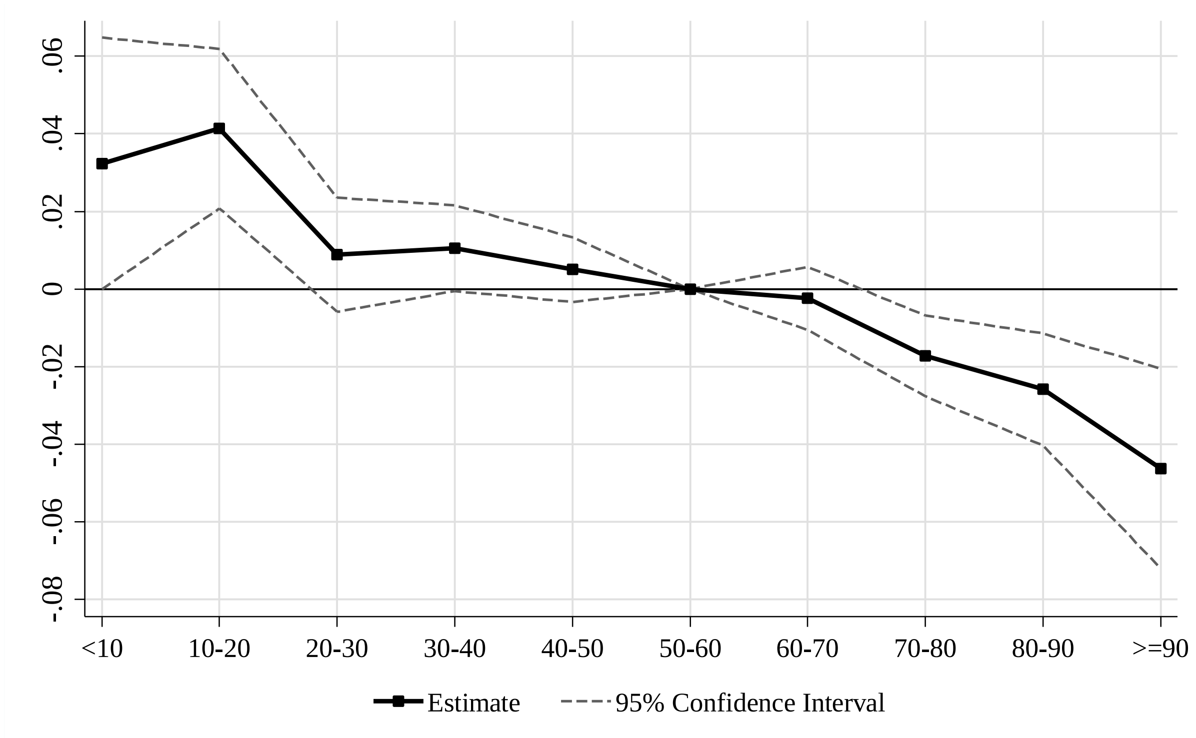
First, global warming increases the risk of hazardous heat exposure.(7, 8) If individuals and communities do not continuously adapt to warming temperatures, the risk of direct heat exposure increases. Second, unless the costs of adaptation decline in proportion to the increase in temperature, the additional resources consumed by adaptive investments and changes in behavior are likely to reduce well-being, too.(2) Third, compounding the increase in average temperature is an increased incidence of heat waves that may result in less predictable risks of heat exposure and adaptation costs.(9, 10) We therefore hypothesize that heat exposure can and will continue to lower emotional well-being in the US population.

To date there has been no comprehensive analysis of the relation between temperature variation, global warming and emotional well-being in the US. Previous studies have found measures of emotional well-being used in this study to be sensitive to individual and contextual factors,(11, 12) but little is known about their sensitivity to temperature.(13, 14) There is strong evidence linking heat to interpersonal aggression, ranging from horn-honking in traffic, to physical assault and civil war.(15) Furthermore, preliminary evidence suggests that heat has adverse effects on mental health.(16–18) Studies on mortality find a U-shaped relationship, with both extreme cold and extreme heat increasing mortality risks.(1, 2, 19) The heat-mortality effect appears to decline with economic development and is smaller in areas with typically hot temperatures.(20)

RESULTS

Our main result in Fig. 1 is the estimated response of emotional well-being to temperature exposure. The dependent variable is an index of well-being with mean zero and standard deviation one constructed as the first principal component of six survey well-being measures that query respondents' well-being on the day prior to the day of interview, such as "Did you feel well-rested yesterday?". In Fig. 2, we report results of temperature effects on each measure separately. Temperature exposure is 24-hour average daily temperature in degrees Fahrenheit (°F) on the day prior to the day of interview.

Figure 1. Well-Being and Temperature.



Note: The dependent variable is an index of emotional well-being with mean zero and standard deviation one that was constructed from six survey measures of well-being. The response function shows the estimated change in well-being due to one day spent in a given temperature interval relative to a day spent in the reference interval of 50-60°F. For example, compared to a day with average temperature in the 50-60°F range, a day with average temperatures above 90°F lowers emotional well-being by 4.3% percent of a standard deviation. Source: Gallup G1K and NLDAS2.

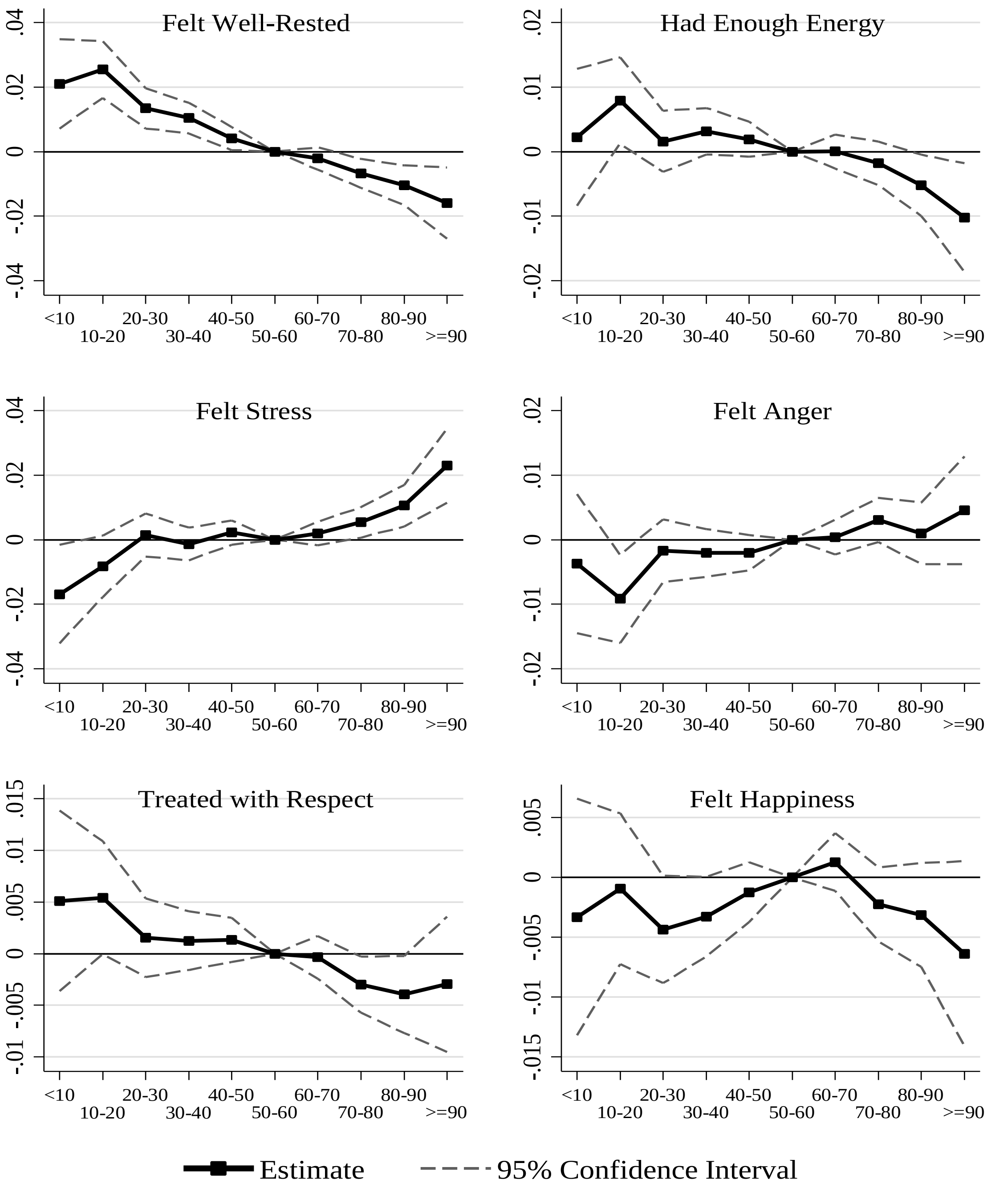
All estimates are obtained using Ordinary Least Squares (OLS) regression. The temperature effects are identified from temperature variation within Zipcode Statistical Tabulation Areas (ZCTAs), i.e. they are adjusted for all time-constant predictors of well-being that differ across ZCTAs in the US. The estimates also adjust for calendar and season effects. Our robustness checks suggest that temperature variation within ZCTAs is as good as randomly assigned. Further details are discussed in the Materials and Methods Section and the Appendix.

We observe no change in well-being at temperatures in the range from 20-70°F. Compared to a day in the 50-60°F reference interval, exposure to one day averaging 70-80°F reduces well-being by 1.7% of one standard deviation ($p<0.01$). Temperatures in the 80-90°F interval reduce well-being by 2.6% ($p<0.001$) and temperatures equal to or above 90°F reduce well-being by 4.6% of a standard deviation ($p<0.001$). Perhaps, surprisingly cold temperatures have symmetrically large positive effects on well-being, with temperature in the 10-20°F range increasing well-being by 4.1% of a standard deviation ($p<0.001$).

To assess the magnitude of the effects, we computed the effect size of other exogenous individual predictors of well-being (Table A3, Appendix). Compared to men, women's levels of well-being are 16% of a standard deviation lower ($p<0.001$), which is consistent with an extensive literature on gender gaps in morbidity and well-being. Compared to having a high school degree, a bachelor degree increases well-being by 11% while a graduate degree increases well-being by 12% of a standard deviation.

Fig. 2 shows temperature effects for the individual well-being indicators that our index is constructed from. Each indicator is a binary variable equal to one if individuals reported having the respective feeling "a lot" on the day prior to the day of interview. The results shed some light on the underlying mechanisms accounting for the effects reported. First, hot temperature increases feelings of tiredness, i.e. not feeling well rested and not having enough energy, while cold temperatures appear to be energizing. Second, hot temperatures increase negative feelings, stress in particular, while cold temperatures lower both feelings of stress and anger. Third, and consistent with the previous result, individuals are also less likely to report to have been treated well, i.e., with respect, by others in hot weather. In the Appendix, we report results on four

Figure 2. Different Indicators of Well-Being and Temperature.



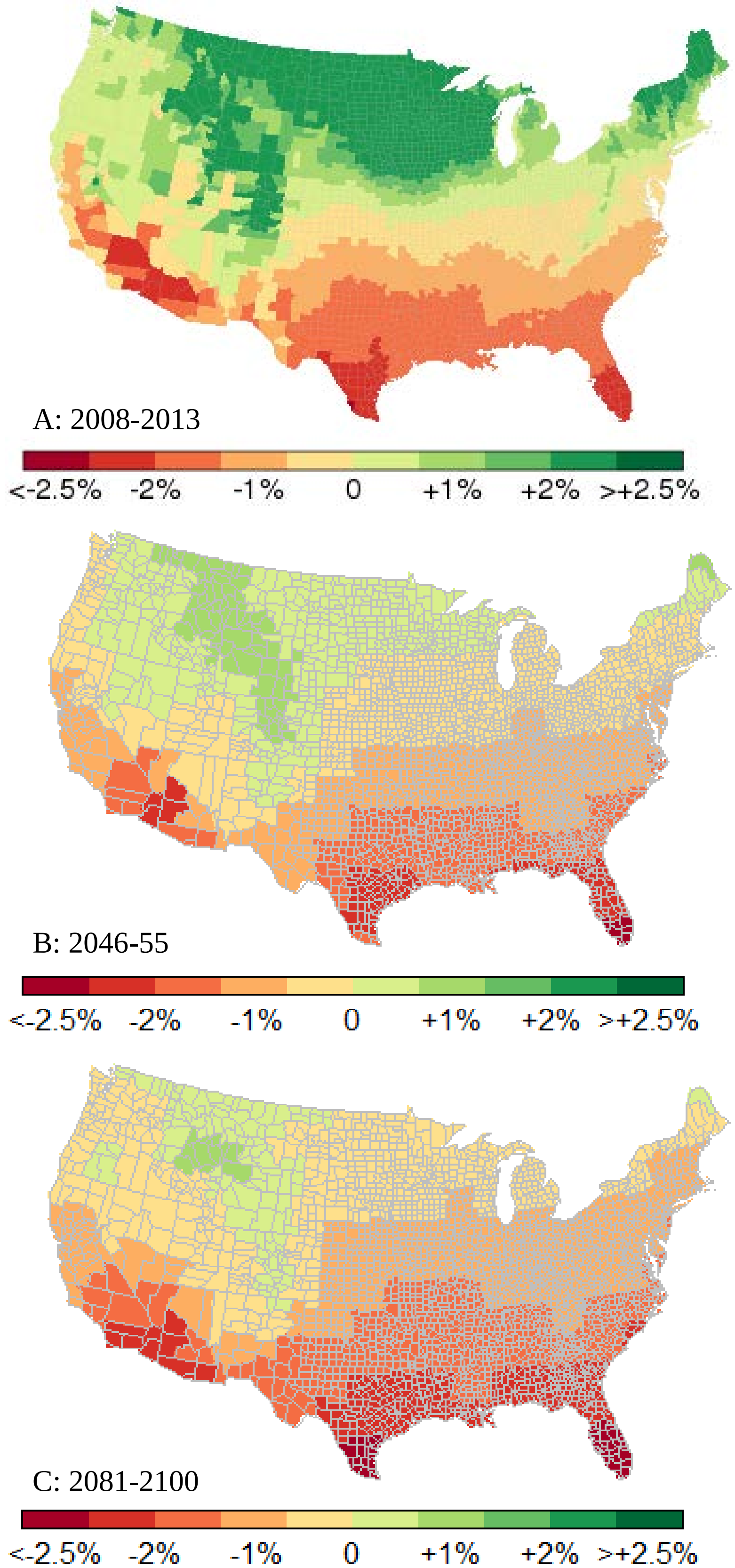
Note: The dependent variables are binary indicator variables equal to one if individuals reported having the respective feeling “a lot” on the day prior to the day of interview. The response functions show the estimated change in the probability of reporting an outcome due to one day spent in a given temperature interval relative to a day spent in the reference interval of 50-60°F. For example, compared to a day with average temperature in the 50-60°F range, a day with average temperatures above 90°F lowers the probability of respondents reporting to feel well-rested by 1.6 percentage points. Source: Gallup G1K and NLDAS2.

additional indicators of well-being that were not included in the index because none of the temperature effects reached statistical significance at the $p<0.1$ level. While effects were not generally statistically significant at the conventional 5% level, we found that heat is associated with lower levels of well-being on all indicators.

Our estimated impact responses shed light on the sub-clinical impact that the changing climate is already having on the lives of Americans. Panel A of Figure 3 maps the annualized well-being loss or gain from the prevailing temperature conditions in a given county for the period from 2008-2013. To produce this map, we calculated the average proportion of days per year individuals were exposed to a given temperature range in a given county, multiplied this proportion with the respective temperature coefficient estimates and then summed over all product terms. We see that at present, a considerable fraction of the contiguous US is exposed to temperature conditions that on average enhance well-being, i.e. northern New England, northern Midwest and high-elevation Mountain West. However, even today the South of the US and California are exposed to temperature conditions that on average lower well-being.

Panel B and C of Figure 3 are produced in identical ways, except that we use the average proportion of days per year individuals will be exposed to a given temperature range the period 2046-55 (Panel B) and 2081-2100 (Panel C). The predicted county temperatures are derived from GFDL-CM3 data, which are based on a coupled general circulation model (CM3) by NASA’s Geophysical Fluid Dynamics Laboratory (GFDL). As temperatures increase over the contiguous US, average well-being drops across the US both because exposure to well-being enhancing cold temperature diminishes in the North and because exposure to hazardous heat conditions increases in the South, Midwest and California.

Figure 3. Well-Being and Global Warming.



Note: The dependent variable is an index of emotional well-being with mean zero and standard deviation one that was constructed from six survey measures of well-being. The maps simulate the annual well-being gain or loss from exposure to average (predicted) temperature conditions in a given county. Source: Gallup G1K and NLDAS2.

While the assumptions underlying these predictions are demanding, they allow us to obtain an initial estimate of the potential well-being impact of global warming. Specifically, we assume that climate change predictions are correct and that apart from climate everything else that could affect the exposure or vulnerability of the U.S. population to temperature extremes will remain constant, such as relative prices of heating and cooling technology, the demography, residential distribution and vulnerability of the US population will remain unchanged. For example, population ageing is likely to exacerbate the well-being costs of global warming, if older Americans well-being response is more sensitive to extreme temperatures, while technology shocks reducing the price of cooling will mitigate the impact of global warming.

DISCUSSION

Using a large nationally representative data on nearly 1.9 Million US adults age 18+ combined with daily temperature data over the period of 2008-13 we find that both extreme cold and heat predict emotional well-being. Temperatures in the range of 20-70°F are not associated with well-being. Temperatures in the range of 70-80°F are associated with a statistically significant, albeit small reduction in well-being, while temperatures excess of 90°F lower well-being by nearly 5% of a standard deviation, which corresponds to around 40% of the well-being gap between high school and college graduates. These effects were mainly driven by increased tiredness and feelings of stress. Perhaps somewhat surprisingly, temperatures below 20°F were found to improve well-being, mainly by reducing tiredness and stress levels. Our robustness checks indicate that our temperature exposure variable is as good as randomly assigned. Finally, using state-of-the-art climate prediction models, we show that global warming will reduce well-being in the US population by reducing exposure to well-being enhancing cold temperatures and increasing exposure to well-being reducing hot temperatures. To our knowledge, this is the first study to have established a causal effect of temperature extremes on emotional well-being in data that is representative for the U.S. population.

Our results are consistent with research that has linked temperature to aggression, and provides individual-level evidence on the underlying mechanisms. We show that negative affect (stress) and reports of individuals not feeling treated with respect increase in extremely hot and diminish in extremely cold weather, suggesting that there is a direct effect of heat on mental affect and behavior.(15) Furthermore, our results also provide micro-level evidence on a hypothesized relationship between temperature and economic growth. Two separate measures indicate that heat drains energy, while cold is energizing which supports previous research finding adverse effects of heat on economic performance.(6, 21)

While our study has numerous strengths, we should consider its limitations. First, like most previous studies on climate and health in the US, this study exploits short-term temperature variation. While our short-term temperature effect estimates have a causal interpretation, they may not be informative about the long-term impact of warming on well-being.(2, 5) Future research will have to incorporate more realistic predictions on potential moderators of the heat-well-being relationship and appropriately account for uncertainties introduced in the estimation and prediction stage of the analysis. In particular, technology will likely continue to improve, while population ageing and growing income inequality may increase the proportion of the population that is vulnerable to temperature extremes. Nevertheless, our estimates are informative about heat effects given current technology and demography, and provide a first baseline for calculation well-being gains or losses due to global warming.

Second, it is not clear whether estimates based on cumulative rather than daily exposure to increased temperature would be similar in magnitude. This constitutes an important topic for future research. Third, we did not address in this study that the effects reported here likely differ across individuals. Older people and individuals with chronic diseases are likely to be more vulnerable, as are poor people, individuals living in crowded urban areas or individuals lacking mental capacity for appropriate adaptive behaviors.(22) Clarifying socio-economic and demographic inequalities in individual vulnerability to climate shocks will be an important topic for further investigation that should also help to clarify the potential roles of economic growth, inequality and population ageing as moderators of the effect of global warming on well-being.

REFERENCES

1. Barreca A, Clay K, Deschênes O, Greenstone M, Shapiro JS (2013) *Adapting to climate change: The remarkable decline in the u.s. temperature-mortality relationship over the 20th century* (National Bureau of Economic Research Working Paper 18692. Cambridge, MA: National Bureau of Economic Research).

2. Deschênes O, Greenstone M (2011) Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US. *Am Econ J Appl Econ* 3:152–185.

3. Deschênes O, Moretti E (2009) Extreme Weather Events, Mortality, and Migration. *Rev Econ Stat* 91:659–681.

4. Weisskopf MG et al. (2002) Heat wave morbidity and mortality, Milwaukee, Wis, 1999 vs 1995: an improved response? *Am J Public Health* 92:830–833.

5. Deschênes O (2012) *Temperature, Human Health, and Adaptation: A Review of the Empirical Literature* (National Bureau of Economic Research Working Paper 18345. Cambridge, MA: National Bureau of Economic Research).

6. Zivin JG, Neidell M (2014) Temperature and the Allocation of Time: Implications for Climate Change. *J Labor Econ* 32:1 – 26.

7. IPCC (2013) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* eds T. F. Stocker et al. (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA).

8. Sherwood SC, Huber M (2010) An adaptability limit to climate change due to heat stress. *Proc Natl Acad Sci U S A* 107:9552–9555.

9. Hansen J, Sato M, Ruedy R (2012) Perception of climate change. *Proc Natl Acad Sci* 109:E2415–E2423.

10. Schär C et al. (2004) The role of increasing temperature variability in European summer heatwaves. *Nature* 427:332–336.

11. Deaton A, Stone AA (2014) Evaluative and hedonic wellbeing among those with and without children at home. *Proc Natl Acad Sci* 111:1328–1333.

12. Kahneman D, Deaton A (2010) High income improves evaluation of life but not emotional well-being. *Proc Natl Acad Sci* 107:16489–16493.

13. Connolly M (2013) Some Like It Mild and Not Too Wet: The Influence of Weather on Subjective Well-Being. *J Happiness Stud* 14:457–473.

14. Lucas RE, Lawless NM (2013) Does life seem better on a sunny day? Examining the association between daily weather conditions and life satisfaction judgments. *J Pers Soc Psychol* 104:872–884.

15. Hsiang SM, Burke M, Miguel E (2013) Quantifying the influence of climate on human conflict. *Science* 341:1235367.

16. Hansen A et al. (2008) The effect of heat waves on mental health in a temperate Australian city. *Environ Health Perspect* 116:1369–1375.

17. Maes M, De Meyer F, Thompson P, Peeters D, Cosyns P (1994) Synchronized annual rhythms in violent suicide rate, ambient temperature and the light-dark span. *Acta Psychiatr Scand* 90:391–396.

18. Page LA, Hajat S, Kovats RS (2007) Relationship between daily suicide counts and temperature in England and Wales. *Br J Psychiatry J Ment Sci* 191:106–112.

19. Curriero FC et al. (2002) Temperature and mortality in 11 cities of the eastern United States. *Am J Epidemiol* 155:80–87.

20. Hajat S, Kosatky T (2010) Heat-related mortality: a review and exploration of heterogeneity. *J Epidemiol Community Health* 64:753–760.

21. Heal G, Park J (2013) *Feeling the Heat: Temperature, Physiology & the Wealth of Nations* (National Bureau of Economic Research Working Paper 19725. Cambridge, MA: National Bureau of Economic Research) Available at: http://www.nber.org/papers/w19725 [Accessed September 15, 2014].

22. Zanobetti A, O'Neill MS, Gronlund CJ, Schwartz JD (2012) Summer temperature variability and long-term survival among elderly people with chronic disease. *Proc Natl Acad Sci U S A* 109:6608–6613.

MATERIALS AND METHODS

Data

We use data on 1.8 million Americans for the period from 2008 to 2013 to quantify the impact of short-term temperature variation on a comprehensive measure of emotional well-being. Our measures of well-being come from the Gallup G1K dataset, a telephone survey of approximately 1000 individuals aged 18+ on each day over the six-year period 2008-2013. To account for nonresponse and disproportionalities in selection, Gallup weights the data on a daily basis. Weights are calculated to match targets from the U.S. Census Bureau by age, sex, race and ethnicity, education, region and population density of self-reported location. The data are also weighted to match national targets of phone status (cell phone only, cell phone with unlisted land line, land-line only etc.). The weighted sample is therefore representative of 90% of the U.S. population in terms of residential location and demographic characteristics. The unweighted sample size is 1,869,505.

Our outcome is based on respondents' self-assessed well-being on the day prior to the interview. Respondents are asked "Did you experience the following feelings A LOT OF THE DAY yesterday?" and then interviewers go through the following list: enjoyment, worry, sadness, stress, anger, and happiness. Additional items are: "Did you smile or laugh a lot yesterday?", "Did you have enough energy to get things done yesterday?", "Were you treated with respect all day yesterday?", and "Did you feel well-rested yesterday?" For each item, respondents can answer either yes, no, don't know, or refuse to answer. We omitted respondents who answered "don't know" or who refused. To reduce the information into a single indicator, we performed principal components analysis and extracted the first principal component from six items that were most strongly predicted by temperature: feeling well-rested, having enough energy, feeling stress, feeling anger, having been treated with respect, and feeling happiness. We also analyzed each item mentioned above separately. The first principal component explained 56% of the variation in the six times. In the Appendix, we report results for additional well-being indicators

These survey data are matched to historical weather information from North American Land Data Assimilation System (NLDAS2) using survey dates and respondents' self-reported zip codes that are then linked to Census Bureau Zip Code Tabulation Areas (ZCTAs). Our temperature exposure is the 24-hour average temperature on the day prior to the interview, split into ten 10°F intervals.

Estimation

All estimates reported are derived from Ordinary Least Squares (OLS) regression using sampling weights provided by Gallup. Standard errors are adjusted for clustering of respondents at the zip-code level. Following recent work in epidemiology and economics, our econometric identification strategy is based on the co-variation between well-being and temperature within ZCTAs, controlling for unobserved, time-invariant effects which are specific to individual ZCTAs (13, 15), including time-constant determinants of non-response. In addition, we flexibly control for season and calendar effects. We include year-by-calendar week fixed effects (FE) to adjust for the effect of year-specific week effects, e.g. due to holidays or historical events. We also adjust for state-specific month FE to control for state-specific seasonal variation. We also include state-by-year fixed effect to adjust for unobserved state-specific year-to-year changes. Finally, we also add controls for day of the week. Robustness checks reported in the Appendix also an extensive set of individual predictors of well-being that be confounded with temperature variation (respondents' gender, age, race, education, marital status, income, number of children, and religiosity) as well as weather controls (relative humidity, precipitation). These checks indicate that temperature variation within ZCTAs is as good as randomly assigned.

APPENDIX

Appendix Table 1. Descriptives Analysis Sample.

Variable		%
Well-Being Index, mean (std. dev.)		0.0 (1.0)
Felt Anger Yesterday		13.9
Felt Enjoyment Yesterday		84.7
Enough Energy To Get Things Done Yest.		85.9
Felt Happiness Yesterday		88.4
Felt Sadness Yesterday		17.7
Smiled/Laughed a Lot Yesterday		82.6
Felt Stress Yesterday		39.9
Felt Treated with Respect Yesterday		92.1
Felt Well-Rested Yesterday		70.6
Felt Worry Yesterday		31.8
Year	2008	16.9
	2009	16.8
	2010	16.7
	2011	16.5
	2012	16.6
	2013	16.6
Month	January	8.5
	February	7.8
	March	8.7
	April	8.3
	May	8.5
	June	8.4
	July	8.5
	August	8.8
	September	8.4
	October	8.6
	November	8.1
	December	7.4
*Week**	mean (std. dev.)	26.3 (14.8)
*Age in Years**	mean (std. dev.)	47.8 (17.7)
Percent Age Missing		1.2
Gender	Men	48.1
	Women	51.9
Race	White	73.3
	Other	3.4
	Black	10.8

Variable		%
Race	Asian	1.8
	Hispanic	8.5
	Missing	2.2
Education	Less than high school	10.9
	High school	29.3
	Technical/Vocational school	6.0
	Some college	22.6
	College graduate	17.2
	Postgraduate work or degree	13.4
	Missing	0.7
Marital Status	Single, never married	22.1
	Married	54.3
	Separated	2.2
	Divorced	9.5
	Widowed	7.0
	Domestic partnership	4.5
	Missing	0.5
Monthly Household Income	<60$	1.5
	$60 – $499	1.4
	$500 – $999	5.7
	$1,000 – $1,999	12.6
	$2,000 – $2,999	11.8
	$3,000 – $3,999	9.9
	$4,000 – $4,999	8.7
	$5,000 – $7,499	13.9
	$7,500 – $9,999	5.9
	$10,000 and over	10.7
	Missing	17.9
Number of Children in Household	0	62.4
	1	15.0
	2	13.4
	3	5.9
	4 or more	3.1
	Missing	0.2
Religion Important in Life	Yes	55.6
	No	29.0
	Missing	15.4

Variable		%
Temperature (°F)	<10	0.4
	[10-20)	1.6
	[20-30)	6.1
	[30-40)	10.4
	[40-50)	14.4
	[50-60)	17.9
	[60-70)	19.6
	[70-80)	18.6
	[80-90)	9.7
	>=90	1.3
Relative Humidity (%)	<10	0.1
	[10-20)	1.4
	[20-30)	2.7
	[30-40)	3.6
	[40-50)	4.9
	[50-60)	9.3
	[60-70)	19.7
	[70-80)	32.9
	[80-90)	22.5
	>=90	2.9
Precipitation (kg/m^2)	0.00	28.0
	(0.00-0.05)	31.9
	[0.05-0.10)	9.9
	[0.10-0.20)	11.7
	[0.20-0.30)	6.8
	[0.30-0.40)	4.2
	[0.40-0.70)	5.2
	>=0.70	2.3

Note: N = 1,868,304. All entries are sample percentages unless otherwise noted. *Age and week are entered as categorical variables into the analysis.

Appendix Table 2. Temperature Well-Being Relationship.

Temperature in °F	% of Sample	M1 = Baseline	M2 = M1 + Individual Controls	M3 = M2 + Climate Controls
<10	0.4	0.032 (0.017)	0.036* (0.016)	0.037* (0.016)
[10-20)	1.6	0.041*** (0.010)	0.042*** (0.010)	0.042*** (0.010)
[20-30)	6.1	0.009 (0.007)	0.013 (0.007)	0.013 (0.007)
[30-40)	10.4	0.011 (0.006)	0.012* (0.005)	0.012* (0.006)
[40-50)	14.4	0.005 (0.004)	0.006 (0.004)	0.006 (0.004)
[50-60) = Reference Group	17.9			
[60-70)	19.6	-0.002 (0.004)	-0.002 (0.004)	-0.002 (0.004)
[70-80)	18.6	-0.017** (0.005)	-0.017** (0.005)	-0.017** (0.005)
[80-90)	9.7	-0.026*** (0.007)	-0.024** (0.007)	-0.024** (0.007)
>=90	1.3	-0.046*** (0.013)	-0.042** (0.013)	-0.045** (0.013)
DFM		1,105	1,223	1,239
Individuals		1,868,304	1,868,304	1,868,304
ZCTA FE		Yes	Yes	Yes
Year-Week FE		Yes	Yes	Yes
State-Month FE		Yes	Yes	Yes
State-Year FE		Yes	Yes	Yes
Weekday FE		Yes	Yes	Yes
Individual Controls			Yes	Yes
Climate Controls				Yes

Note: DFM = Degrees of Freedom (not counting ZCTA FE). ZCTA = Zipcode Tabulation Area. FE = Fixed Effects. Individual Controls: age, gender, race, education, marital status, household income, number of children, religiosity (see Table A1, for descriptives). Climate controls = Relative humidity, precipitation (see Table A1, for descriptives). Table A2 contains the in-sample distribution of the temperature exposure variable (column 1), estimates of the well-being temperature response function from the baseline model (column 2) and robustness checks (columns 3-5). The dependent variable is a well-being index with mean zero and standard deviation one. The index is the first principal component extracted from six well-being measures (feeling well-rested, having enough energy, feeling stress, feeling anger, having been treated with respect, and feeling happiness) capturing respondents emotional well-being on the day prior to the interview. Temperature is measured as the 24-hour average temperature in degrees Fahrenheit (°F) on the day before the interview. All estimates were obtained using OLS regression and use sampling weights provided by Gallup. The estimates are adjusted for Zipcode Tabulation Area (ZCTA) fixed effect, year-week fixed effects, state-year fixed effects, state-month fixed effects and day of the week fixed effects.

Appendix Table 3. Temperature Well-Being Relationship.

Temperature in °F	Anger	Enjoyment	Enough Energy	Happiness	Sadness	Smiled or Laughed	Stress	Treated with Respect	Well Rested	Worry
<10	-0.004	-0.011	0.002	-0.003	-0.006	-0.003	-0.017*	0.005	0.021**	0.000
	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.008)	(0.004)	(0.007)	(0.007)
[10-20)	-0.009**	-0.004	0.008*	-0.001	-0.007	-0.004	-0.008	0.005	0.025***	-0.005
	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)	(0.003)	(0.004)	(0.005)
[20-30)	-0.002	-0.007**	0.002	-0.004	-0.001	-0.009**	0.002	0.002	0.013***	0.006
	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
[30-40)	-0.002	-0.005**	0.003	-0.003	-0.000	-0.008***	-0.001	0.001	0.010***	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)
[40-50)	-0.002	-0.002	0.002	-0.001	-0.000	-0.002	0.002	0.001	0.004*	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
[50-60) = Ref.										
[60-70)	0.000	0.004**	0.000	0.001	-0.002	0.001	0.002	-0.000	-0.002	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
[70-80)	0.003	-0.001	-0.002	-0.002	0.000	-0.002	0.005*	-0.003*	-0.007**	0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
[80-90)	0.001	-0.002	-0.005*	-0.003	0.003	-0.001	0.011**	-0.004*	-0.010**	0.005
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
>=90	0.005	-0.003	-0.010*	-0.006	0.002	-0.002	0.023***	-0.003	-0.016**	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.003)	(0.006)	(0.006)

Note: † = Item not included in well-being index analyzed in Table A2 and Figure 3. Number of observations = 1,868,304. The dependent variables are binary indicators of respondents self-reported feelings, e.g., of happiness or anger, on the day prior to the interview. The items are further described in the Materials and Methods section. Temperature is measured as the 24-hour average temperature in degrees Fahrenheit (°F) on the day before the interview. All estimates were obtained using OLS regression and use sampling weights provided by Gallup. The estimates are adjusted for Zipcode Tabulation Area (ZCTA) fixed effect, year-week fixed effects, state-year fixed effects, state-month fixed effects and day of the week fixed effects.