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Projected Behavioral Impacts of Global Climate Change

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Abstract

The projected behavioral impacts of global climate change emanate from environmental changes including temperature elevation, extreme weather events, and rising air pollution. Negative affect, interpersonal and intergroup conflict, and possibly psychological distress increase with rising temperature. Droughts, floods, and severe storms diminish quality of life, elevate stress, produce psychological distress, and may elevate interpersonal and intergroup conflict. Recreational opportunities are compromised by extreme weather, and children may suffer delayed cognitive development. Elevated pollutants concern citizens and may accentuate psychological distress. Outdoor recreational activity is curtailed by ambient pollutants. Limitations and issues in need of further investigation include the following: lack of data on direct experience with climate change rather than indirect assessments related to projected changes; poor spatial resolution in environmental exposures and behavioral assessments; few rigorous quasi-experimental studies; overreliance on self-reports of behavioral outcomes; little consideration of moderator effects; and scant investigation of underlying psychosocial processes to explain projected behavioral impacts.

Contents

INTRODUCTION

Global climate change (GCC) is a dynamic, multidimensional system of changes in environmental conditions that will likely influence human behavior. Although there is a robust literature on the likely physical health impacts of GCC (see, for example, Levy & Patz 2015, Watts et al. 2015), little analysis of the projected behavioral impacts of GCC has occurred. The psychological analysis of GCC has focused on attitudes and decision making (Clayton et al. 2015, Gifford 2011, Swim et al. 2011), with some work centering on how adults (Reser & Swim 2011) and children (Ojala 2012) cope with the threat of GCC. Forty-five percent of Americans (Saad 2017) and similar proportions of Western Europeans (Steentjes et al. 2017) are very worried about GCC.

Before discussing the projected behavioral impacts of GCC, I describe two ethnographies that investigate the direct psychological impacts of GCC. Cunsolo Willox et al. (2012) interviewed Inuit residents of a Canadian polar region that has already undergone environmental changes including elevated temperature, decreased ice extent, rising sea levels, and altered flora and fauna. The researchers used qualitative interviews that did not explicitly probe about GCC to explore community members' emergent experiences with their environment. Residents noted disruptions in access to land and sea that supported traditional hunting and fishing practices. They also reported elevated family stress due to more time spent at home and boredom. Several community members also commented on the compounding of preexisting mental health problems due to these alterations in lifestyle. Nearly all residents bemoaned threats to their cultural heritage, identity, and attachment to place. Standard surveys assessing residents' responses converged with the qualitative data. In a qualitative study of another Inuit community, Durkalec et al. (2015) documented how shifts in the patterns of sea ice critically affected hunting along with cultural identity and freedom to travel. Many interviewees noted that greater unpredictability of sea ice conditions over time made it difficult to travel throughout the region as had been custom for

centuries. This contributed to feelings of entrapment and isolation and threatened navigational competency, a key component of cultural heritage.

This review explores the projected behavioral impacts of GCC created by elevated temperature, extreme weather (storms, drought, flooding), and increased air pollution—all well-documented sequelae of GCC.[1] Where prior reviews exist, I summarize their conclusions focusing on more rigorous research designs and updating them when possible. For topics for which there are no reviews, I summarize existing trends, again emphasizing more rigorous research designs. Two important caveats should be kept in mind. Given that GCC is a slowly evolving set of processes that, with the exception of a few ethnographies, has not been directly examined, the behavioral impacts I describe are projected. Furthermore, it is impossible to randomly assign human exposure to climatic variation, therefore challenging our ability to provide causal evidence of the projected behavioral impacts of GCC.

HEAT: PROJECTED BEHAVIORAL IMPACTS

Mental Health

Research on mental health and temperature has focused on psychopathology and quality of life. The relation between high temperatures and suicide has long been of interest, but given the complex etiology of suicide and the difficulties in isolating temperature as a predictor, this is a controversial topic (Deisenhammer 2003). An 11-year time series analysis of all deaths in the United Kingdom found that when temperatures exceeded 18°C, there was a 3.8% increase in the relative risk of suicide for each 1°C increment (Page et al. 2007). When ambient temperatures rise well above mean levels, mental health admissions in hospitals increase (Hansen et al. 2008, Vida et al. 2012, Wang et al. 2014). These studies incorporated seasonality and day of week controls along with other meteorological factors.

Temperature is also associated with quality of life. A panel study including 67 countries found that the warmer the coldest month of the year, the happier the country (Rehdanz & Maddison 2005). Conversely, the warmer the hottest month of the year, the less happy the country. The authors included in their model numerous variables to help rule out alternative explanations (e.g., economic indicators, sociocultural factors such as religious denominations, health indices like life expectancy, and meteorological factors). They also modeled 30- and 60-year future happiness in light of GCC-projected increases in temperature. Countries at higher latitudes are predicted to experience increased happiness, whereas tropical and subtropical countries should become less happy. These temperature and quality-of-life data illustrate that the degree of spatial resolution in climate variation and behavior matters. Even though GCC consists of macro-level global alterations, the potential impacts of GCC can vary at a much smaller level of resolution.

Social Interaction

Comparisons of different geographic regions, seasonal fluctuations within the same region, and concomitant measurements of temperature and aggression reveal an increase in interpersonal

[1]I identified papers in Google Scholar, Medline, Psychological Abstracts, and the Social Sciences Citation Index using terms such as climate change, global warming, temperature, heat, air pollution, weather, floods, sea rise, drought, rainfall, disasters, and natural disasters. I then scanned any article including the words psychology, behavior, mental health, quality of life, psychopathology, human welfare, economic, stress, anxiety, depression, PTSD, interpersonal relationships, aggression, conflict, crime, violence, war, civil war, physical activity, recreation, leisure, outdoor activity, migration, relocation, refugees, cognitive development, learning, school, absenteeism, social support, and social capital. I also conducted reference chasing within every article, chapter, or book on GCC and related terms on physical or mental health.

aggression as ambient temperatures rise above the thermal comfort zone (approximately 24–27°C at 45% relative humidity) (Anderson et al. 2000, Burke et al. 2015). Given existing US data on assaults, murders, and annual temperatures in a set of 50 US cities over a 48-year period, Anderson et al. (2000) calculated that an average annual increase of 2°F in the United States would result in nine additional violent crimes per 100,000 persons per year. This translates into approximately 24,000 additional murders/assaults projected each year per 2°F rise in average ambient temperatures. Relying upon estimates from a 30-year panel study of monthly US county crime rates and temperatures, Ransom (2014) and Houser et al. (2015) predicted similar increases in violent crime with projected temperature elevation, along with widespread increases in property crime.

Several recent meta-analyses utilizing fluctuations in temperature for the same population over time indicate elevated intergroup conflict with rising temperature. Burke et al. (2015) noted that temperature was linked to violence in 83% of 55 longitudinal studies, with stronger impacts for intergroup compared to interpersonal conflict [respectively, 11.3% and 2.1% increase for a 1 standard deviation (SD) increase in temperature]. These estimates incorporated location-specific fixed effects and a Bayesian analysis accounting for mean effect sizes and inter-study heterogeneity. Current estimates of expected global temperature by 2050 range from 2 to 4 SD elevations across the globe (Watts et al. 2015). Other meta-analyses of temperature rise and conflict from longitudinal data come to similar conclusions, including one using historical data spanning centuries (Hsiang & Burke 2014, Hsiang et al. 2013). The largest increases in intergroup conflict occur in low-income regions with dependence on agriculture. Worldwide armed conflicts over a 30-year period were coincident 9% of the time with major heat waves or droughts; in countries with a high degree of ethnic fragmentation, the incidence became 23% (Schleussner et al. 2016). Limitations of the temperature and conflict data include the following: insufficient spatial resolution, given that climatic variation data are often unavailable at a fine grain; covariation of temperature and rainfall; lack of attention to local political and sociocultural sources of conflict; selection bias because of longitudinal data in the meta-analyses; temporal variation (e.g., duration, lag effects); and a general absence of information on underlying mechanisms accounting for temperature effects (Buhaug & Thiesen 2012, Scheffran et al. 2012). Nonetheless, the consistency and rigor of the meta-analyses along with empirical assessments of several of these limitations lead to the conclusion that both interpersonal and intergroup conflict will increase with rising temperature, with stronger impacts for intergroup conflict.

Several psychological processes may underlie the robust relation between temperature elevation and conflict. As temperatures rise above thermal comfort levels, individuals feel more irritated and hostile (Anderson et al. 2000); moreover, people spend more time outdoors during the evening as temperatures increase (Cohen & Felson 1979, Rotton & Cohn 2001). Environments that are harsh and unpredictable produce accelerated life histories characterized by earlier reproduction and unstable interpersonal relationships, greater risk taking, truncated future time horizons, and poorer self-control (Ellis & Del Giudice 2014). Hotter countries and hotter states within the United States have earlier maternal first births, more limited future time perspectives, and lower levels of self-control (van Lange et al. 2017). Elevated temperatures covary with reduced rainfall, and both damage crop yields. As shown below, drought appears to heighten conflict indirectly because of economic distress and resource scarcity (Burke et al. 2015). Climate-related migration could also indirectly affect conflict via economic pressure because of insufficient infrastructure (e.g., housing) and unemployment. As a threat, GCC is also capable of increasing authoritarian attitudes. Fritsche et al. (2012) experimentally manipulated perceived threat of GCC: Adults in the GCC threat condition showed heightened authoritarian beliefs and were more likely to denigrate deviant social groups.

Recreational Activity

Outdoor recreational behaviors and tourism opportunities are being transformed by rising temperatures. As one illustration, truncated ski seasons worldwide have already begun (Scott et al. 2012). In temperate climates, as temperatures rise, people's use of parks and other outdoor public spaces increases (Nikolopoulou et al. 2001). However, once ambient temperatures begin to rise beyond the thermal comfort zone, outdoor activities are curtailed (Lin 2009, Zacharias et al. 2001). Physical activity is also altered by temperature. In temperate climatic regions, people engage in greater outdoor physical activity in warmer months compared to colder ones (Tucker & Gilliland 2007). However, in hot climates, physical activity diminishes in the warmer months of the year (Baranowki et al. 1993). In a study of recreational and commuter bicyclists in Vienna, Brandenburg et al. (2007) found that very high temperatures (>40°C) suppressed recreational but not commuter cycling.

There are important limitations in the analyses of climate and recreational activity. Geographic location should be incorporated into these models, because rises in ambient temperature increase outdoor recreation in colder climates but depress it in temperate regions when the thermal comfort zone is exceeded. Moreover, people's expressed preferences vary with destination: For instance, people prefer warmer temperatures at the beach compared to the mountains (Scott et al. 2012). Finally, analyses of ambient temperatures and recreational activity have largely ignored the most common American outdoor activities of gardening and local walking.

WEATHER DISASTERS

Quality of Life and Stress

Studies of drought, flooding, and severe storms indicate relationships between these GCC-related events and diminished quality of life and elevated stress.

Drought. Both life satisfaction (Carroll et al. 2009) and psychological well-being (Coehlo et al. 2004) suffer with prolonged drought. Australian farmers list unpredictable financial circumstances and drought as the most common sources of life stress (Staniford et al. 2009). Community forums among Australian farmers suffering prolonged drought reveal a profound sense of loss coupled with escalating frustration with government regulations (Polain et al. 2011). The latter illustrates a secondary stressor in relation to a projected behavioral impact of GCC: Drought leads to more contact and reliance upon governmental programs and private entities (e.g., banks, insurance companies) to provide assistance. Droughts are associated with falling employment rates as well as increased financial pressure among farmers (Edwards et al. 2009). Drought has also been directly linked with chronic physiological stress. Rainfall reductions led to significant increases in cortisol among poor farmers in Kenya but had a negligible impact on factory workers in the same region (Haushofer & Fehr 2014). Parallel data were uncovered in self-reported stress. The differential impacts of droughts on farmers vis-à-vis factory laborers suggests an economically mediated impact, given the dependence of farmer's livelihood on rainfall. This moderation effect also reduces the plausibility of alternative explanations of drought effects on stress.

Focus groups with Australian Aboriginal communities revealed feelings of loss along with concerns about damage to cultural identity and mental health because the drought interfered with traditional hunting and gathering practices (Rigby et al. 2011). These findings are similar to the ones uncovered by ethnographic work among indigenous peoples in Canadian polar regions (Cunsolo Willox et al. 2012, Durkalec et al. 2015). Additional qualitative work with Australian

youth suffering prolonged droughts in agricultural areas reveals more psychological distress. This includes anxiety about family pressures and turmoil, concern about the erosion of household and community economic resources, social isolation because of families leaving the area, and need to spend more time working on the farm (Carnie et al. 2011).

Floods. Immediately prior and 18 months following flooding in a rural Korean village, overall quality of life dropped (Heo et al. 2008). Persons who reported greater flooding impact (e.g., property loss, injury) had greater decreases in quality of life. Following the flooding, rates of posttraumatic stress disorder (PTSD) were much higher than Korean norms, as were levels of mild depression. In their systematic review of floods and mental health, Fernandez et al. (2015) identified additional indirect impacts of secondary stressors such as dealing with bureaucratic intransience (e.g., flood insurance), marital tension, and financial pressure.

Mental Health

Common psychological reactions to extreme weather disasters such as prolonged drought, floods, and hurricanes or typhoons include depression, PTSD, anxiety, and heightened family tension. PTSD is the most studied mental health consequence of disasters. For instance, 68% of studies following natural and human disasters reviewed by Norris et al. (2002) documented elevated PTSD symptoms, and Galea et al.'s (2005) review estimated a 30–40% prevalence rate of PTSD for both natural and human disasters. In their meta-analysis of human and natural disasters (not including drought), Rubonis & Bickman (1991) calculated an overall effect size (ES) for mental health outcomes of $r = 0.174$, with anxiety having the largest ES. Norris et al. (2002) concluded that 10.2% of persons in natural disasters experienced transient stress, 55.7% prolonged stress, 21.6% significant distress or psychopathology, and 12.5% very severe impairment (see Galea et al. 2005; Goldman & Galea 2014; Neria et al. 2008, 2009; Norris et al. 2002; Rubonis & Bickman 1991; Warsini et al. 2014 for overviews on the mental health correlates of natural disasters). ES heterogeneity in Rubonis & Bickman's (1991) meta-analysis indicated three factors that independently elevated ES. In descending order of magnitude, these are number of fatalities (an indirect indication of severity of exposure), immediacy of event, and natural versus human disasters. Norris et al. (2002) and Goldman & Galea (2014) in their narrative reviews of much larger and more recent reviews of mental health and disasters agreed with the first two factors but concluded that human disasters showed a higher prevalence of psychopathology compared to natural disasters largely because of greater severity of exposure. Studies of natural disasters typically include a wide range of exposed persons, whereas most human disasters focus on the direct victims. The more recent reviews of disaster and mental health converge on two factors that compound reactions to disasters: severity of exposure and preexisting mental health issues. Other less robust moderators include greater risk for citizens of low socioeconomic status (SES), which may be a result of both greater exposure and fewer resources to cope. Women tend to be more susceptible to PTSD and depression, whereas men more commonly suffer from substance abuse. Elementary-aged children are more prone to suffer from PTSD and anxiety, and persons with social support fare better following disasters. In their summary of disaster impacts, Norris et al. (2002) found a higher rate of very severe impairment for children (29.6%) compared to adults (18.3%). In their systematic review of epidemiological studies of floods and hurricanes, Murray et al. (2011) also concluded that children appear to be more vulnerable to storm-related PTSD compared to adults, but they cautioned that the number of child PTSD studies is small. Several indirect post-disaster sources of stress also appear to accentuate adverse mental health outcomes, including residential displacement, economic strain, marital tension, and frustrations because of interactions with government

and private bureaucracies (e.g., temporary housing, flood insurance) (Goldman & Galea 2014, Norris et al. 2002).

Major storms. Longitudinal studies of severe storms and mental health with comparison groups are rare. Over a 7-year period, American counties experiencing one hurricane had a 31% increase in suicides, whereas remaining counties without a hurricane showed no increases (Krug et al. 1998). Chronic fatigue syndrome (CFS) patients affected by Hurricane Andrew had significant elevations in CFS symptoms compared to CFS patients living away from the impact zone (Lutgendorf et al. 1995). Moreover, the more intense the storm's impact, the greater the elevation in symptoms. Both self-ratings and physician assessments converged. Researchers compared the mental health of Korean adults 3 months after a typhoon in heavily damaged and unaffected communities with retrospective reports of symptoms prior to the storm (Chae et al. 2005). Pre-typhoon levels were comparable and remained stable for the unaffected communities, but in the affected communities the levels of depression, psychological distress, anxiety, and PTSD significantly increased. Using US monthly mental and physical health data, Sastry & Gregory (2013) constructed a large representative sample of New Orleans residents over a 20-month period prior to Hurricane Katrina and then another large representative sample from the same population for the following 12 months. Propensity scores enabled the construction of matched samples on multiple parameters related to physical and mental impairments in the absence of the predictor(s) of interest. Overall, the researchers found a 50% increase in mental impairments, defined as a mental or emotional condition lasting 6 months or more that caused difficulty in learning, remembering, or concentrating. African American female adults emerged as a particularly vulnerable subgroup, whereas persons over 65 showed little impact.

Longitudinal studies of hurricane and typhoon victims without comparison groups show increases in psychological distress following weather disasters (Amstadter et al. 2009, Norris et al. 2009, Rhodes et al. 2010). Moreover, the greater the severity of the storm's impact on the household, the higher the adverse psychological outcomes. Comparing cross-sectionally representative surveys of adults living in the New Orleans region 2.5–3.5 years before and 6 months after Hurricane Katrina, researchers found a 7% and a 10% increase in serious and moderate mental disorders, respectively (Kessler et al. 2006). Interestingly, suicide ideation dropped somewhat after Katrina, which appeared to reflect beliefs about one's ability to rebuild one's life and recognition of one's inner strength. In a 1-year follow-up, Kessler et al. (2008) found continued high levels of moderate mental disorders and an increase in more serious disorders as well as PTSD. Moreover, the apparent drop in suicide ideation had reversed, likely fueled by the long and difficult recovery process.

Following major storms, the prevalence of serious emotional disturbances among children and youth increases substantially (La Greca et al. 1998, McLaughlin et al. 2010, Warheit et al. 1996), with some youth showing symptoms as much as 3 years later. Weems et al. (2007a) found no changes in PTSD, depression, or anxiety 17 months prior to Katrina compared to 6–7 months afterward in a sample of children. The timing of the assessments may explain these null findings.

A few correlational studies of storms and mental health merit attention because of their unique findings. Prevalence of PTSD is higher following major storms and does not appear to fade over time (Murray et al. 2011). One month after Hurricane Katrina, adults more seriously affected by the storm had higher levels of anxiety disorders and PTSD than those less affected, after controlling for multiple sociodemographic factors (Galea et al. 2007). Comparison of PTSD rates for the low- versus high-exposure groups indicated nearly a doubling of prevalence. Two (Abramson et al. 2008) and three years after Katrina (Picou & Hudson 2010), residents continued to have raised levels of serious psychological distress as well as PTSD symptoms. This was especially true

for citizens more affected by the hurricane, with more children at home, more financial difficulties, and smaller social networks. There is also evidence that adults with greater psychological distress prior to Katrina were more likely to experience PTSD afterward (Lowe et al. 2013). Nearly half of all New Orleans' school children ($n > 2{,}000$) in the year following Katrina had PTSD levels indicating need for referral (Osofsky et al. 2009). One year later, referral prevalence dropped slightly from 49% to 42%. Major vulnerability factors included severity of storm impact, mortality of family/friend, separation from parents, and especially displacement. Previous loss or trauma, elementary (relative to middle) school age, and female sex also elevated vulnerability.

Drought. In a systematic review of predominantly cross-sectional drought and mental health studies, Vins et al. (2015) uncovered elevated risk for adverse mental health impacts, with the greatest vulnerability among rural populations dependent upon agriculture. Vins et al. (2015) found direct or indirect evidence in over a third of the reviewed studies that economic loss accounted for drought-related psychological distress. In a qualitative study among middle- and low-income farmers in the midst of a prolonged drought in Iran, Keshavarz et al. (2013) noted widespread worry about money, particularly among poorer farmers. The authors also uncovered several indirect aspects of financial pressure. Lack of income and escalating debt led to reduced self-esteem and concerns about social reputation in the community. Children's higher education had to be altered or postponed, and girls were more likely to delay marriage because of financial investments in weddings and dowries. Marital strain related to providing for the family was apparent, and tensions with neighbors rose around disputes over irrigation water.

There are only a few quasi-experimental studies on drought and mental health. Chin (2010) demonstrated worse mental health among farmers living in Malawian communities with less rainfall. Chin showed that these linkages to general mental health were moderated by land ownership, with those owning farms most strongly affected. Employing nationally representative Australian data in the year following a 7-year drought, OBrien et al. (2014) identified five clusters of long-term drought conditions that reflected patterns of rainfall and dryness throughout the 7-year drought. They matched these various rainfall measures at a fine-grain level of geographic resolution, providing a level of precision not achieved in most rainfall and mental health studies. With abundant covariates—including prior mental and physical health plus multiple sociodemographic indices—they found that two drought patterns were particularly associated with elevated psychological distress. One pattern reflected 20–32 months of prolonged days of extreme dryness, and the other combined this cluster with a recent period of at least 12 months of such conditions. The latter association was strong, indicating a 6.22% increase in cases of psychological distress for persons living in rural areas. For persons in metropolitan districts, drought patterns were unrelated to psychological distress. These findings illustrate the potential importance of duration and timing of exposure for weather and behavioral outcomes. Two other Australian studies suggest more serious mental health consequences of prolonged drought, with associations to increased suicides (Hanigan et al. 2012, Nicholls et al. 2006). Both studies incorporated seasonal suicide trends, season, and temperature as statistical controls. Hanigan et al. (2012) illustrate the importance of considering moderating variables in thinking about GCC and mental health. They uncovered a considerably stronger link between drought and suicide among rural males than detected among the total population by Nicholls et al. (2006).

Floods. In a systematic review of the predominantly cross-sectional literature on flooding and mental health, Fernandez et al. (2015) documented consistent evidence of heightened psychological distress as well as greater PTSD prevalence following flooding. Suicide data were more equivocal. Several studies found a dose-response relationship, with higher flood damage exposure

associated with worse mental health outcomes. In general, there is good convergence between qualitative and quantitative findings. Children separated from their parents or those with low social support are a vulnerable subgroup for adverse mental health outcomes, although the data base for this finding is small. The elderly are at risk for greater physical injury, but the data are inconclusive for mental health sequelae. Similar conclusions on flooding and mental health appear in other reviews restricted to epidemiological data (Ahern et al. 2005, Crabtree 2012, Murray et al. 2011).

A few studies report pre- and post-flood data and include comparison groups assessed over the same time periods. The incidence of psychiatric symptoms among female residents of council homes (subsidized housing) in Bristol, England whose homes were badly flooded tripled in comparison to council home residents not flooded (Bennet 1970). Male residents of the flooded homes had more new physical health complaints, but new psychiatric symptoms remained low and constant over time. Immediately before and 11–20 months after major flooding and discovery of waterborne toxin exposure in Missouri, PTSD symptoms increased relative to a comparison sample (Robins et al. 1986). The number of defined PTSD cases, however, was small and remained so over the period. In additional analyses, men but not women showed significant increases in depression and alcohol abuse relative to unexposed men (Solomon et al. 1987). There was some indication that this gender interaction was because men felt a high social burden to provide for their households. Larger changes in depression occurred among residents of Iowa exposed to floods compared to those unexposed, with pre-flood depression levels comparable for the two groups (Ginexi et al. 2000). Increases in depression were accentuated among lower-income individuals and those who lived in small rural towns. Among individuals aged 70 and over in the Iowa floods, however, flood exposure did not increase depression (Tyler & Hoyt 2000). Furthermore, social support buffered the adverse effects of flooding for citizens under 70. Stimpson (2006) also noted that the flood-related elevations in depression in Iowa had a reciprocal association with diminished perceived control over time (e.g., giving the survey response "I have little control over the bad things that happen to me").

Similar to Tyler & Hoyt (2000), Phifer (1990) found evidence of elevated depression as well as anxiety among residents aged 55–64 after flooding in Kentucky, but not among those over 65. In terms of overall well-being, males but not females also showed significant elevations. Furthermore, the impacts of flooding on changes in all of these symptoms were greater for persons of lower occupational status. Puerto Rican residents had a significant increase in depression symptoms pre- and post-flooding, whereas those unaffected showed no changes (Canino et al. 1990). Alcohol abuse did not change. Post-flooding only, flood victims showed a greater incidence of new PTSD cases and were more likely to visit a mental health service compared to their non-flooded counterparts. Elderly residents of rural regions of Australia had greater increases in anxiety before and after exposure to major flooding, whereas a comparison group over the same period had stable levels of anxiety (Bei et al. 2013). Depressive symptoms, however, did not increase in either group pre- and post-flood. Pre-flood mental health measures were all equivalent. Furthermore, after the flooding, persons had higher levels of PTSD symptoms; the greater the severity of the flood impact, the bigger the difference in PTSD symptoms between flood victims and non-victims. For instance, persons forced to evacuate had PTSD symptoms four time higher than those not affected by floods. New England preschool children 6 months prior and after major flooding showed elevated externalizing symptoms. Boys also showed more anxiety (Burke et al. 1982), whereas girls unexpectedly showed a decrease in anxiety. During the previous year in the same time period no such changes occurred among a well-matched sample. Over a 7-year period, American counties experiencing one major flood had a 13.8% increase in suicides, whereas remaining counties with no floods had a stable rate of suicides (Krug et al. 1998).

Pre/post-flooding studies without comparison groups also suggest adverse mental health sequelae, including psychological distress among children and adolescents (Felton et al. 2013, Ollendick & Hoffman 1982). Powell & Penick (1983) collected data on psychological distress from Mississippi Valley flood victims who had been displaced from their homes with retrospective recall of 1 month prior to the disaster, 2–3 months after the flood, and again 13–18 months post-flooding. At the 1-year follow-up, most respondents had been resettled into permanent housing, primarily in the same communities where they had live previously. Distress levels were higher immediately and 1 year later compared to pre-flood levels. There was no difference in immediate and longer-term follow-up levels of distress. In addition, at the 1-year follow-up, residents were queried if they had ever received counseling or treatment for "nervous, emotional, or mental health problems." Of the respondents who replied affirmatively, 17% reported receiving counseling after the flood, 17% both before and after the flood, and 8% before the flood only. In several French municipalities heavily damaged by flooding, the rates of new daily prescriptions for psychotropic medications increased by 54% in the 3 weeks following the flooding in comparison to the prior 2 years (Motreff et al. 2013). Seasonal trends in prescription volume covaried. In two Australian cities that experienced major flooding, suicide rates during the first 6 months post-flooding were not higher than those for the same 6-month interval 11 years prior (De Leo et al. 2013). The absence of an immediate post-flood effect on suicide is consistent with earlier findings by Kessler et al. (2006), who found a slight decrease in suicides immediately after Hurricane Katrina that then rose 1 year later (Kessler et al. 2008).

Some unique cross-sectional data are described below. In the Norris et al. (2004) study of two Mexican villages, rates of PTSD were 24%, 18%, 11%, and 11% at 6, 12, 18, and 24 months after a flood, respectively. The greater the level of devastation, the higher the prevalence of PTSD, with the relation between severity and PTSD being strongest 6 months after the disaster. Data for cases of major depression were more linear over time (9.1%, 7.9%, 6.8%, and 5.9% over the same time periods, respectively). Frankenberg et al. (2008) generated a dose-response function between extent of tsunami damage (objectively assessed by remote sensing) and PTSD symptomatology in over 20,000 adults. Major predictors of this function were exposure to traumatic events (e.g., witnessing drownings). Statistical controls included multiple sociodemographic indicators. Furthermore, symptoms subsided over a period of 1 year, but the rate of symptom reduction was associated with tsunami damage severity.

Displacement

Current estimates suggest GCC will lead to ~150 million people being displaced worldwide in the next 50 years due to coastal flooding and soil degradation from drought and flood-related soil erosion (Watts et al. 2015). In their systematic review of drought and mental health, Vins et al. (2015) found that after economic hardship, the next most common pathway linking decreased rainfall with psychological distress was emigration. Involuntary relocation precipitates psychological distress along with elevated chronic physiological stress (Hollifield et al. 2011). Vins et al. (2015) also noted that loss of sense of community and social isolation exacerbated the harmful mental health sequelae of droughts. Two months after Hurricane Katrina, the farther citizens had to evacuate from home, the worse their PTSD symptoms and the higher their psychological distress (Weems et al. 2007b). Levels of diagnostic screening for major depression among displaced adults residing in FEMA trailers in Louisiana and Mississippi following the Gulf hurricane disasters of 2005 were seven times higher than the national average at that time (Larrance et al. 2007).

The impacts of natural disasters on displaced children are of particular concern (Kousky 2016, Masten & Narayan 2012), especially in underdeveloped countries (Bartlett 2008), as the experience

of being separated from their caregivers compounds the trauma already associated with the disaster. For instance, following Hurricanes Katrina and Rita in the United States, more than 5,000 children became separated from their parents, and over 34,000 calls were made to an emergency hotline for missing and exploited children (Natl. Comm. Child. Disasters 2010). Adolescent displaced into relocation camps by Hurricane Katrina had higher levels of psychological distress and depression relative to well-matched controls unaffected by the storm (Vigil & Geary 2008).

Destruction of habitat not only alters the structure and predictability of daily life, but it also disrupts place attachment (Hollifield et al. 2011, Reser et al. 2011). Threats to identity and competency from unpredictability and changes in place were central themes in ethnographic work among indigenous people in the Canadian polar region as well as among Aboriginal peoples in drought-stricken regions of Australia (Cunsolo Willox et al. 2012, Durkalec et al. 2015, Rigby et al. 2011). Nearly 60% of New Orleans' residents reported mild to severe losses from Hurricane Katrina, with many exhibiting clinical symptoms of grief (Shear et al. 2011). Persons displaced by extreme weather are more prone to psychological distress than those affected but able to remain in their community (Hollifield et al. 2011). Natural disasters also disrupt social networks, eroding a key coping resource. Extreme weather also strains mental health service delivery systems.

Cognitive Development

Extreme hydrological conditions are related to deficits in children's cognitive development because of malnutrition, lack of access to school, and increased child labor (Baez et al. 2010). For example, rural children in Zimbabwe exposed to severe drought conditions during the first two years of life had higher rates of stunting (being short for one's age, an indicator of malnutrition) (Hoddinott & Kinsey 2001). Furthermore, this drought-related stunting rendered children less likely to start school on time and slowed their progress through the early grades (Alderman et al. 2006). Rural Vietnamese children showed similar drought-related patterns of stunting and schooling progress (Thai & Falaris 2014). Children aged 7–15 in Cote D'Ivoire regions hit by droughts experienced a 40% drop in school enrollment relative to normal rainfall periods as well as in comparison to regions with normal rainfall during the same time period (Jensen 2000). Researchers found similar rainfall-related shifts in school enrollment in rural regions of India (Jacoby & Skoufias 1997). Flooding can also affect nutrition. The aftermath of excessive rainfall in Nicaragua because of Hurricane Mitch included increased infant malnutrition (Baez et al. 2010), and in Bangladesh severe flooding led to more stunting in children under five years of age (Del Ninno & Lundberg 2005) and to undernutrition in older children, particularly those from the poorest households (Foster 1995).

Early experiences of malnutrition can have lifelong impacts. Maccini & Yang (2009) used random weather shocks in the form of diminished rainfall in rural areas of Indonesia to examine the relation between drought periods at birth and adult educational attainment. Women, but not men, showed diminished educational attainment if they had been born during periods of drought, which the authors attributed to income losses during the early childhood period. These effects may reflect in part malnutrition because of tight finances, given that women born in periods of less rainfall were also significantly shorter. The authors speculated that boys might have been protected from the harmful impacts of drought because of prejudice against female offspring.

Extreme weather-related reductions in school enrollment may also happen because of inaccessibility to schools as well as heightened pressures to increase child labor to compensate for lost agricultural revenues. Flooding and severe storms knock out roads and destroy school buildings. For instance, following Hurricanes Katrina and Rita in 2005, one-fourth of Louisiana school children had to change schools because their own building was unusable (Pane et al. 2008). Not

surprisingly, these displaced children evidenced drops in achievement, which were exacerbated among those displaced for longer periods of time. Major weather disasters in economically underdeveloped countries reveal even more extreme school building destruction that often takes years to be remedied (Kousky 2016).

In countries with child labor, children are much more likely to drop out of school and return to the fields or factories because of disaster-related financial burdens on families. Baez et al. (2010) as well as Kousky (2016) review several studies showing that extreme weather events increase use of child labor to compensate for household income losses due to flooding, droughts, or severe storm damage. Children who withdraw from school to help supplement household income are much less likely to return to school once the crisis has subsided. For instance, flooding in Nicaragua from a large hurricane reduced school retention and slowed grade progression (Ureta 2005).

Social Interaction

Fluctuations in extreme precipitation (floods or droughts) have been associated with increased interpersonal and intergroup conflict. In a series of meta-analyses of longitudinal studies of deviations in rainfall from the mean, including one with Bayesian analyses of mean and variance in effect sizes, researchers have uncovered consistent but relatively modest effect sizes on the order of a 0.3% increase in interpersonal violence and a 3.5% increase of intergroup conflict following 1 SD change in rainfall (Burke et al. 2015, Hsiang & Burke 2014, Hsiang et al. 2013). Note that deviations from the mean are the principal index employed: Too much or too little rain is what matters. Even young children may be affected. Children aged 2–9 were evaluated approximately 6 months before and after flooding in Bangladesh: Aggressive behaviors increased 10% (Durkin et al. 1993). One possible mechanism to explain the link between extreme hydrological events and crime is income shock created by abnormal rainfall. Most studies on precipitation extremes and crime have occurred in agrarian regions where agricultural disruption caused by too much or too little rain has major consequences on economic livelihood (Hsiang et al. 2013). Dramatic changes in precipitation could also prompt movement from rural to urban areas and thus exacerbate competition for resources such as jobs and housing. Many of the same methodological limitations noted above in the case of temperature elevation and conflict studies apply here, but they have been largely addressed in these meta-analyses.

A smaller number of studies have examined aggression and conflict following severe storms. Following Hurricane Katrina, high school students who had experienced greater exposure were more aggressive, which may have been mediated by PTSD as well as emotional regulation deficits (Marsee 2008). Among displaced adults residing in FEMA trailers following Hurricane Katrina, incidents of intimate partner violence rose three times more than normative levels among women living in FEMA trailers (Larrance et al. 2007). In another sample, women with greater exposure to Hurricane Katrina were substantially more likely to experience intimate partner violence after controlling for extensive sociodemographic factors (Harville et al. 2011). One possible pathway linking severe weather events and child well-being is parental stress and child maltreatment. For instance, a dramatic rise in child abuse following Hurricane Floyd was noted in North Carolina (Keenan et al. 2004).

Although a number of studies indicate that social support can buffer some of the adverse impacts of weather disasters (Goldman & Galea 2014, Masten & Narayan 2012, Kaniasty & Norris 2009, Norris et al. 2002), it is important to also recognize that disasters can severely strain socially supportive relationships. Displacement from home and school, prolonged stress, and elevated household tension and conflict are common sequelae of weather disasters.

Recreational Activity

Using national daily activity data, Connolly (2008) showed that for men there was a reliable reduction in leisure activity on rainy days, whereas women were less affected; similarly, across several North American cities outdoor walking was curtailed on days with rain or snow (Montigny et al. 2012). Similar trends have also been noted for leisure cycling (Brandenburg et al. 2007). About 10% of American middle-aged women in a nationally representative sample remarked that bad weather was a major barrier to physical activity (Wilcox et al. 2000), and in a study of Australian mothers of young children (Currie & Develin 2002), inclement weather was a major reason for curtailing outdoor activity with children. Some studies, however, found no significant relations between physical activity and bad weather (King et al. 2000, Sallis et al. 1989).

GCC-related shifts in precipitation, particularly during temperate seasons, might have adverse impacts on psychological well-being by constraining outdoor recreational activities conducive to stress reduction. Not only do people have a preference for natural settings with trees and water, but exposure to nature also facilitates recovery from chronic stress induced by such things as job strain or cognitive fatigue (Hartig et al. 2014, Kaplan & Kaplan 1989). Unseasonably cold and wet summers at the higher latitudes curtail outdoor activities, constraining recreational opportunities and possibly diminishing resources for coping with stress. Employing time series analysis with extensive temporal, sociodemographic, and meteorological controls, Hartig et al. (2007) documented greater antidepressant use among Swedish adults during cool and wet summers. They also found lower birth weights among male Swedish infants who were in utero during cool and wet summers (Hartig & Catalano 2013). The gender-specific impact on birth weights comports with a large literature on male vulnerability to prenatal stress.

AIR POLLUTION: PROJECTED BEHAVIORAL IMPACTS

Air pollution will rise because of several aspects of GCC. Heavy precipitation increases molds and other bioallergens. Drought contributes to wildfires, which elevate fine particulates and several gaseous pollutants. Higher temperatures accelerate the production of photochemical oxidants such as ozone. Research pertinent to the potential impacts of GCC on human behavior and air pollution has focused on awareness and concern, mental health, and outdoor recreation.

Awareness and Concern

The public is cognizant of air pollution, with upwards of 80% of individuals reporting some awareness (Evans & Jacobs 1982, Evans et al. 1988). The public, unlike the experts, tends to rely upon visual cues of air pollution, primarily reductions in visibility and soiling of buildings (Evans & Jacobs 1982, Winter 1999). Citizens in metropolitan areas express widespread concern about pollution, ranking it among the top five community problems (Evans & Jacobs 1982, Evans et al. 1982); levels of pollutants and publicity about the problem are the primary predictors of public concerns (Evans & Jacobs 1982, Ferrer-i-Carbonell & Gowdy 2007).

Mental Health and Quality of Life

Several investigators have examined temporal fluctuations in air pollution over time in relation to psychiatric problems, including suicide (Yang et al. 2011), psychiatric 911 calls (Rotton & Frey 1984), and psychiatric ER visits (Briere et al. 1983; Szyszkowicz 2007; Szyszkowicz et al. 2009, 2010). These associations incorporate statistical adjustments for meteorological factors (e.g., temperature), temporal parameters such as season and day of

week, and economic trends. In addition to time series analyses of pollutants and mental health, some work has also employed a case-crossover methodology, with similar positive results linking pollutants to psychiatric disorders (Kim et al. 2010, Szyszkowicz et al. 2010). In this technique, a person who has committed suicide (Kim et al. 2010) or made a psychiatric visit to the emergency room for suicidal ideation (Szyszkowicz et al. 2010) represents a case. For each of these persons, air pollution conditions on the day of the case are recorded, and other days from the same month and year when the case did not have a psychiatric emergency are chosen as comparison conditions. Air pollution conditions for these control days are also recorded. Thus, each case serves as their own control, and the researchers can compare their psychiatric status under different levels of pollution. This design is suitable when persons have intermittent exposure to risk factors that vary over time and have a transient impact.

Instead of examining more severe indices of psychiatric disorder, a few investigators have explored possible linkages between pollutants and psychological distress among the general population. Employing a time series design, Bullinger (1989) showed that anxiety and depression tracked fluctuations in ambient outdoor pollution levels. Ozone, the primary toxin components of photochemical smog, is associated cross-sectionally and over time with psychological distress among residents of the Los Angeles metropolitan area (Evans et al. 1987, 1988). Furthermore, this association appears to be amplified among citizens experiencing one or more stressful life events (e.g., divorce) within the previous 3 months. Nurses with greater residential particulate exposure (net of a host of statistical controls) are more likely to have high anxiety symptoms (Power et al. 2015). There is also experimental evidence that exposure to polluted scenes increases anxiety (Lu et al. 2018).

Like outdoor temperatures, pollutants may be capable of aggravating aggression and conflict, but the quantity and quality of the evidence for this effect pales in comparison to that available for high temperatures. Daily changes in 911 calls for domestic violence in a 2-year time series design were positively associated with changes in daily ozone, with covariates for multiple meteorological factors including temperature, season, day of the week, and holidays (Rotton & Frey 1985). In a 9-year panel study of US cities, as pollution levels increased, crimes per year rose (Lu et al. 2018). Fixed-effects analyses of city-level changes through the years along with extensive statistical controls provide strong quasi-experimental evidence for this relation. Younon et al. (2017) found a positive association between chronic exposure to particulates and juvenile delinquency in a longitudinal study. Their multilevel modeling incorporated extensive personal, meteorological, and other pollutant controls. Interestingly, laboratory studies also show that pollution exposure elevates irritation and anger (Jones & Bogat 1978, Rotton et al. 1979) as well as unethical behavior (Lu et al. 2018).

Economists have also become interested in estimating costs of pollution to quality of life, finding evidence that polluted air is associated with lower quality of life. As an illustration, Luechinger's (2010) analyzed quality of life over a 15-year period in 13 European countries using extensive economic covariates and modelling unobserved variables through an instrumental variable technique. Interestingly, the adverse impacts of elevated pollutants were greatest among older adults. In a longitudinal analysis of several countries, Welsch (2010) showed that changes in air quality were related to changes in quality of life.

Because poor air quality affects children's health, an indirect effect of elevated pollution could be reduced school attendance. School absenteeism tracks alterations in air pollutants over time (Gilliland et al. 2001, Park et al. 2002, Ransom & Pope 1992). These longitudinal analyses included extensive meteorological, sociodemographic, and temporal statistical controls. In Gilliland et al. (2001) and Park et al. (2002), non-illness absenteeism was unrelated to pollutants. Furthermore, in each of the above studies, pollutants of lower magnitude and with less variation over time were unrelated to absenteeism. Currie et al. (2009) documented an association between carbon

monoxide levels and school absenteeism among 39 urban school districts in Texas over a 5-year span. For each 6-week attendance period—controlling for school characteristics, year, attendance period, the statistical interactions among each of these factors, and weather—variation in carbon monoxide was significantly related to changes in absenteeism. As an additional check on the validity of the findings, measures of attendance temporally lagged behind carbon monoxide were also significantly related to attendance whereas attendance data assessed prior to carbon monoxide levels were not. The magnitude of the apparent carbon monoxide pollution effects was not trivial, with one additional school day exceeding pollution standards predicting a 9% increase in absenteeism within the 6-week attendance period.

Recreational Activity

To minimize respiratory health effects during high periods of pollution, the public is advised to restrict outdoor physical activity. Studies indicate that when pollutant levels rise, persons reduce outdoor recreational activities, including physical exercise (Chapko & Solomon 1976; Evans et al. 1982, 1988; Roberts et al. 2014; Salmon et al. 2003). Interestingly, several of these studies show little impacts on indoor recreational activities, adding weight to the validity of the relation between ambient pollutants and outdoor recreational behaviors. In a more rigorous analysis with a regression discontinuity design, Neidell (2010) showed that attendance at the Los Angeles Zoo dropped substantially when smog alerts were issued. Multiple temporal variables as well as other pollutants and meteorological factors were incorporated into the modeling.

METHODOLOGICAL AND CONCEPTUAL CHALLENGES

Because GCC is a complex system of multiple processes that are evolving slowly throughout the globe, it is challenging to directly assess its impact on human behavior. Delineation of pre- versus post-GCC impact within the same population or estimation of exposure dose across populations is fuzzy. Furthermore, with the exception of a handful of small qualitative case studies of individuals in global regions where some ecological changes (e.g., loss of sea ice) have been most dramatic, the evidence for behavioral impacts of GCC has to be constructed by examining literatures on weather-related events (i.e., temperature rise, extreme hydrological cycles and storm activity, elevated air pollution) that are projected to change with GCC.

A major challenge in studying human responses to weather is exposure estimation. Available data on both weather and human behavior at the appropriate scale to assess exposure are scarce. Data on rainfall need not only to include amount and variability but also to reflect the degree of actual human exposure. The resolution required to do this accurately is often not achievable with archival meteorological data. Shade, reflective surfaces, and water all influence the temperature individuals experience. In addition, there can be considerable variability in mitigation factors that may affect accurate exposure estimation. The degree of covariation between outdoor temperatures and indoor climatic conditions can vary greatly (e.g., due to building insulation, cooling systems). Moreover, although people spend the majority of their daily time indoors, the extent of movement into and out of buildings is highly variable and difficult to track on an individual basis. Housing construction quality, height above ground, flood control infrastructure, and extent of underlying water table are relevant to flood and drought. Moreover, following a major storm, the most severely affected victims may not be reachable or may be too traumatized to participate in research. In many cases, a subset of the storm-affected population may have evacuated.

Exposure estimation is not just a methodological challenge; there are also vexing conceptual issues to consider. Consider for example rainfall and air pollution: What exactly should the metric be? Flooding or drought each refer to deviations from normal precipitation. In the latter case,

duration is obviously salient to human responses, and in the former, the speed of onset and the extent of knowledge about the impending flooding are likely important. In thinking about behavioral responses to air pollution, should we focus on current levels, or is some period of aggregated exposure more appropriate? Regardless of whether a point or continuous estimate is selected, are the impacts expected to be immediate or to take time to emerge? Furthermore, one can readily imagine nonlinear impacts in terms of both degree of exposure and temporal influences on human behavior. Recall, for instance, that both quality of life and recreational activity have curvilinear associations with ambient temperature. It is also worth reiterating that changes in seasonal patterns of temperature and precipitation can interfere in complex ways with recreational opportunities. For instance, as mentioned previously, colder and wetter summers at higher latitudes interfere with recreational activities (e.g., hiking), and analogous changes in winter activities (e.g., skiing) happen during warmer winters. One of the complexities of understanding GCC and behavioral impacts is the different implication of global shifts in weather for different regions of the world.

In addition to the appropriate estimation of GCC-related exposure, the unit of analysis for outcomes is another issue worth thinking more about. As a psychologist, I have focused herein on projected individual behavioral responses to GCC-related weather conditions. As indicated, there is considerable work documenting likely escalations in intergroup conflict resulting from elevated temperature, drought, and food system strains. I also briefly noted that GCC could undermine or at least strain social support systems. There are other behavioral outcomes at higher levels of aggregation potentially linked to GCC. For instance, legal, financial, and planning policies may shift either in anticipation of expanding GCC impacts or in response to more severe and frequent disasters (Vogel et al. 2016). Training and deployment of government employees (e.g., first responders, military) will likely evolve as well to try to meet the demands of GCC.

Because we cannot randomly assign people to weather conditions, issues of selection bias loom large in evaluating cause and effect. This problem is exacerbated by difficulties in constructing homogenous groups of individuals with variable exposure or in tracking the same individuals before and after weather events. Many of the weather-related changes accompanying GCC are gradual, which means we need to construct panels at the appropriate time intervals to capture the change. The longer the time interval of climate change, the more difficult it is to establish a comparable cohort of individuals before and after the weather change. Furthermore, at the macro level various sociocultural, political, and historical conditions that affect behavior can vary between locations or over time, especially over longer periods of time.

A prominent selection bias factor is SES. Persons with more resources typically reside in places with lower probability of adverse weather and pollution exposure and in homes with greater mitigation capacity. Moreover, higher-SES individuals are more likely to have better resources to cope after a disaster, and they either do not suffer secondary adverse impacts (e.g., job loss) or have accumulated assets and other benefits (e.g., health or flood insurance) that facilitate effective coping. Residential sorting in some instances could also take place because of weather preferences or tolerance for exposure to risk. If these preferences are also related to behavioral outcomes of interest, estimates of weather/behavioral indices may be inflated. Devising comparable homogenous groups of individuals pre- and post-exposure (let alone comparing cross-sectionally between groups) raises serious challenges to internal validity.

In addition to potential confounding factors such as personal and geographic area characteristics, isolation of the presumed environmental factor presents further difficulties. Precipitation, temperature, and pollutants all covary and have seasonal, daily, and even hourly patterns that make it difficult to establish cause and effect. Another concern in the GCC and behavior literature is the predominance of self-reported indices of behavior. This can lead to over- as well

as underestimation of weather-behavior relations. If a principal index of exposure to weather is self-reported (e.g., the extent of property damage following a storm) and the outcome is also self-reported (e.g., depression or PTSD), it is hard to disentangle the role of negative affect as well as the direction of causality (e.g., do I have greater distress because of more adverse storm exposure or do I report more exposure because I am more distressed)? Underestimation can also happen because of multiple contributors to self-reported outcomes, including in some cases a reasonable amount of unspecified measurement error. Ideally, we want objective assessments of exposure and multi-methodological indicators of outcomes. When only self-reported outcomes are feasible, use of well-developed, psychometrically sound instruments is necessary.

CONCLUSION

Despite these methodological challenges, there is sufficient evidence to argue that GCC will likely cause adverse human behavioral outcomes. First, granted difficulties in precisely gauging environmental exposure, a consistent finding in the storm, flood, and drought literatures is that the greater the exposure of individuals within affected populations, the more adverse the impact. Second, studies of the same persons over time, aggregates of persons over time (e.g., school samples), or cross-sectional comparisons of homogenous samples with respect to SES reveal associations between variation in weather or pollution and behavior. Third, more rigorous quasi-experimental field studies tracking the same individuals over time before and after exposure and comparing them with groups from the same population who are unexposed show that GCC-projected changes in weather are likely to produce alterations in human behavior. Time series analyses that examine how changes in the behavioral outcome track changes in the weather variable and that incorporate statistical controls for temporal variations (e.g., seasonality) also provide converging evidence. In some of these panel studies, location-specific fixed effects are incorporated to capture variation within the location or institution over time. Fourth, there have also been some a priori weather-by-moderator analyses that are hard to ascribe to confounding. As an illustration, studies of drought show that persons more dependent upon water for economic livelihood (e.g., farmers) fare worse than their peers (e.g., factory workers) following a drought. As another example, elevated ambient pollution alters outdoor recreation much more than indoor recreational activities. Fifth, in the few instances where multi-methodological assessments of behavior have occurred, they were concordant.

Every review article on temperature, weather extremes, and pollution and behavior notes heterogeneity in impacts, which raises two issues. First, such variability, if unaccounted for, can suggest weak or spurious effects. Second, on the other hand, when patterns of strength of effects are discernable, they point toward important moderator variables that condition the impacts of GCC. Some robust patterns that have emerged include the following: Individuals with preexisting mental health conditions are more vulnerable to adverse psychological distress following extreme weather events; low-SES individuals are not only more likely to have greater exposure to elevated temperature, more extreme weather events, and elevated ambient pollution, but they also appear more vulnerable to harmful behavioral outcomes, including conflict and aggression and psychological distress; young children, especially girls in economically underdeveloped countries, are susceptible to declines in cognitive functioning because of malnutrition and impediments to school attendance arising from extreme weather events; and persons with greater social capital show some resilience to extreme weather events. Some additional moderators with less consistent evidence include gender, suggesting that men are more vulnerable to substance abuse and women are more vulnerable to depression and PTSD following disasters; post-disaster lag, indicating a reduction in symptoms as time passes; and occurrence of secondary stressors created by rehousing, interactions with insurance companies, etc.

An important topic for future analysis are the underlying psychosocial processes through which GCC-related alterations in weather and pollution can lead to adverse behavioral outcomes. Perhaps the most studied mediator to date has been economic loss. Several studies, particularly of hydrological extremes, strongly point toward economic loss as an important reason for which GCC could cause psychological distress. Work on pollution and elevated temperature also documents increased negative affect as a potential contributor to adverse behavioral outcomes from GCC. Extreme weather conditions may exacerbate family conflict and turmoil as well. Outdoor activities are sensitive to weather, affecting shifts in recreational activity and access to environments that provide restorative opportunities.

Some weather-related events cause massive displacement, creating climate refugees who have to find new places to live and work. Such changes disrupt social capital, create pressure on infrastructure (e.g., housing), and exacerbate unemployment. Furthermore, alterations of existing communities or relocation to new ones can affect place attachment, with potential implications for mental health (Scannell & Gifford 2017). GCC and many of its accompanying weather-related changes are inherently uncontrollable and frequently lead to greater unpredictability. A high degree of unpredictability and lack of structure in daily routines adversely impact children's cognitive and socioemotional development (Evans & Wachs 2010). Prolonged interaction with social or physical conditions that are unpredictable or uncontrollable can engender helplessness in people. Finally, GCC itself and each of the accompanying alterations in weather described herein represent environmental demands that contribute to stress. How we appraise these conditions and the strategies we use, both personally and collectively, to cope with these demands will affect human behavior.

As global temperatures rise, evidence suggests we may see moderate increases in intergroup conflict, particularly in agrarian communities, as well as modest elevations in interpersonal aggression and crime. Use of the outdoors and recreational activities will undergo major shifts throughout the world following rising temperatures. In colder regions of the world, with rising temperatures we will see an uptake in quality of life and in outdoor recreation activities; in hotter regions, the opposite will happen. Less rigorous evidence suggests elevated temperature is associated with greater psychological distress.

Extreme hydrological cycles creating droughts and floods degrade human well-being. The adverse mental health consequences of drought and flooding are moderate in magnitude and reasonably well substantiated, with anxiety about economic livelihood being a major pathway. There is also a smaller amount of rigorous evidence that rainfall deviations modestly elevate interpersonal violence, particularly in agrarian societies. Excess rain strongly suppresses outdoor physical activity. Abundant evidence shows that major storms accompanied by temporary or permanent relocation moderately elevate psychological distress in many people and PTSD in a sizeable minority of persons; individuals with preexisting psychological disorders are especially vulnerable. Major storms as well as flooding disrupt school attendance, especially in economically underdeveloped countries. Elevated air pollutants concern the public, curtail outdoor activity, and may elevate psychological distress.

An indirect pathway linking GCC to projected human health is poverty. Low-income persons are more likely to experience natural disasters and are less likely to recover economically. Economic micro-simulation techniques predict substantial GCC-related income loss, particularly in underdeveloped countries (Hallegatte & Rozenberg 2017). There are also plausible indirect impacts of GCC on children's cognitive development via malnutrition and accessibility to school in the aftermath of natural disasters. It is also sobering to contemplate the impacts on children's well-being of ubiquitous communications about escalating uncertainty about the future of the planet.

As more and more people directly experience elevated temperatures, excessive shifts in precipitation, and worse air pollution as a consequence of GCC, their physical and mental health will be compromised. Moreover, against the background of gradual increases in the intensity of GCC, the degree of unpredictable jolts of dramatic weather extremes will challenge human adaptive capabilities.

SUMMARY POINTS

1. The projected behavioral impacts of GCC emanate from elevated ambient temperature, increased frequency and severity of droughts and flooding, higher-intensity storms (e.g., hurricanes), and rising ambient air pollution.
2. Rising temperatures will lead to increased intergroup conflict, particularly in agriculturally dependent sectors, with more modest increases in aggression and crime likely to occur at lower latitudes.
3. Weaker evidence suggests a positive association between elevated maximum temperatures and psychological distress.
4. Adverse mental health consequences of droughts and floods are modest and will increase with GCC.
5. Major storms elevate psychological distress in many people and PTSD in some individuals, particularly those with preexisting psychological disorders. There is good evidence of a dose-response relation between storm severity and psychological distress.
6. Elevated ambient pollution concerns the public, curtails outdoor activity, and may increase psychological distress.

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