Climate change and mental health research methods, gaps, and priorities: a scoping review

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Research on climate change and mental health is a new but rapidly growing field. To summarise key advances and gaps in the current state of climate change and mental health studies, we conducted a scoping review that comprehensively examined research methodologies using large-scale datasets. We identified 56 eligible articles published in Embase, PubMed, PsycInfo, and Web of Science between Jan 1, 2000, and Aug 9, 2020. The primary data collection method used was surveys, which focused on self-reported mental health effects due to acute and subacute climate events. Other approaches used administrative health records to study the effect of environmental temperature on hospital admissions for mental health conditions, and national vital statistics to assess the relationship between environmental temperature and suicide rates with regression analyses. Our work highlights the need to link population-based mental health outcome databases to weather data for causal inference. Collaborations between mental health providers and data scientists can guide the formation of clinically relevant research questions on climate change.

Lancet Planet Health 2022; 6: e281–91

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Background

From a methodological standpoint, conducting rigorous research on the relationship between climate change and mental health is challenging. In *The* Lancet *Countdown on Health and Climate Change: from 25 Years of Inaction to a Global Transformation for Public Health*, the authors explain that "a robust methodology for an annual indicator [for mental health] has not been reported, reflecting the complexity of the topic and paucity of data rather than its lack of importance".[1] Because climate change often occurs gradually and on a large scale, and mental health changes related to climate change can be difficult to detect immediately, finding a meaningful relationship between them can be challenging. Research on this topic is also challenging due to the complex biopsychosocial pathways that contribute to mental health. In some cases, mental health effects might be the result of events or experiences that have distal root causes, such as displacement and poverty, which can be triggered or exacerbated by climate events.[2]

Scientific literature on the associations between climate change and mental health is growing, with emerging theoretical models, analytical methods, and datasets.[3–12] The use of large-scale datasets to study climate change-related mental health effects has increased due to the need for adequate sample sizes to detect the effect of subtle changes in temperature on mental health outcomes (eg, mood) at the population level. As these approaches become more popular, it is helpful to examine the key findings and gaps in the field to inform future study. In this Review we summarise large-scale research on the effects of climate change on mental health to advance our understanding of and preparedness for these effects.

Commonly cited explanatory frameworks have proposed that climate change has both direct and indirect effects on mental health.[3,5,6,10,13] Direct effects of climate change on mental health generally include stress-related and trauma-related sequelae of an acute event, such as a hurricane or flood. Indirect effects describe more insidious mental health changes related to physical health, such as increased ambient temperature; increased pollen, dust, or pollution; and community-level effects from economic damages, conflict over scarce natural resources, displacement, or migration due to loss of habitable land. Chronic indirect mental health effects also include helplessness, worry, and fear of rapid climate change (known as solastalgia, ecoanxiety, or climate grief).[14,15]

Climate change can also act as a threat amplifier by magnifying pre-existing economic, racial or ethnic, and health disparities by disproportionately affecting vulnerable and marginalised populations who are already at risk for psychiatric disorders.[16–18] WHO considers climate change a social determinant of mental health, which reflects the view that risk factors for developing mental health disorders are strongly associated with social inequities.[19] Vulnerable and marginalised populations, including people with pre-existing mental illnesses and those experiencing homelessness, are expected to be at higher risk of climate change-associated mental health problems than the general population.[17] Therefore, investigating health-care disparities, structural inequalities, and the effects of public policy is important for research on the effect of climate change on mental health.

The effect of a climate change event on mental health is associated with: (1) the local cultural, social, economic, and developmental context; (2) the spatial distribution of the exposure; (3) the type of meteorological event; (4) the duration and severity of the event; and (5) the anticipated acuity and chronicity of the associated consequences for physical health and community wellbeing (contingent on 1–4).[3,4,6,20] Acute climate change events (eg, hurricanes) have a well defined area and duration of exposure, but the timeline for the onset and course of subsequent mental health effects is less clear. Mental health

consequences have been observed for 5 years following major floods,[21] and some people who lived through Hurricane Katrina in 2005 continued to need trauma-related care more than a decade later.[10] Approaches to measure the association between chronic climate change events (eg, increases in ambient temperature) and indirect effects of climate events (eg, anxiety related to migration) on mental health are less evident.

Research on the effect of climate change on mental health is challenged by the gathering and interpretation of highly subjective measures across different cultures and income settings.[1] Research findings can be difficult to interpret or generalise if regions are differentially affected by climate change. Although high-income countries like the USA have contributed heavily to climate change due to greenhouse gas emissions and industrial activity, the burden of morbidity and mortality because of climate change will largely fall upon low-income nations around the world.[22] This disproportionate impact, which is expected to widen the existing disparities in resources and living environments, must be accounted for in ongoing research questions and methods.

Given these challenges, it is important to examine methodologies and gaps in climate change and mental health research, which has major potential implications for public health and policy change. Identifying the limitations of current methodologies could inform the development of causal pathway frameworks that can help researchers to better understand how and why climate change affects mental health. A comprehensive picture of approaches to study design, data collection, and analytical techniques can guide future work on the direct and indirect effects of climate change on psychiatric symptoms and service needs.

See Online for appendix

Aims of this scoping review

In contrast with previous reviews that have described evidence of climate change's effects on mental health,[3–13] this scoping review summarises the research methodologies—specifically in studies with large-scale samples—used to study climate change and mental health. Other reviews have focused on findings (the what), whereas this study is interested in the approaches (the how) researchers use to ask and answer questions about climate change and mental health. We focused on large-scale datasets because of their utility for studying the chronic effects of climate change in novel ways. Climate change often involves gradual alterations in temperature and detecting mental health effects in response to these subtle changes probably requires large sample sizes for sufficient power. Although we recognise that important research on climate change and mental health is being done without large-scale datasets, we wish to highlight these more comprehensive methodological approaches.

The availability and use of several large databases is new in climate change and mental health research, so a detailed examination of this literature can identify key advances and knowledge gaps. The intersection of population-based databases and meteorological data in particular could enable the investigation of longitudinal effects of climate change and draw causal inferences from the relationship between chronic environmental shifts and mental wellbeing. We sought to gather and synthesise peer-reviewed, empirical, large-scale studies on climate change and mental health to address the following three questions: what types of large-scale investigations have been conducted on the direct and indirect effects of climate change events on mental health; what are the strengths and limitations of the research methods these studies used, and how have they affected the overall body of knowledge to date; and what gaps in the literature inform future investigations of climate change-associated mental health effects using large-scale datasets?

Methods

Methodological overview

A systematic review was initially planned but, given the exploratory and broad nature of this field and our aim to summarise research approaches, a Scoping Review method was selected on the basis of a predetermined protocol in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) standards for scoping reviews.[23] The detailed search strategy and PRISMA extension for Scoping Reviews is in the appendix (p 1).

Search strategy and selection criteria

Full search strategy and selection criteria are presented in the appendix (p 2). We searched PubMed, Embase, PsycINFO, and Web of Science for articles published in English or translated to English from Jan 1, 2000, to Aug 9, 2020 (the date the search was conducted). The start year of 2000 was chosen to detect new literature, as the majority of studies have been published since this date. Search terms, developed with a research librarian to capture relevant literature, included "climate change", "global warming", "extreme weather", "extreme events", "heat wave", "heat waves", "counseling", "psychotherapy", "bipolar", "depression", "anxiety", "depressive", "mania", "schizophrenia", "suicide", "suicidal", "PTSD", "dementia", "homicide", "violence", "substance use", "alcohol", "mental health", "mental disorders", and "mental health services". We included terms for violent behaviours and dementia because psychiatrists are often involved in evaluating these conditions. However, we note that violent behaviours should not be equated with mental illness. Although some psychiatric conditions, if untreated, might increase the risk of aggressive behaviours, people with mental illness are more likely to be victims of violence and crime than the general population and not more likely to be perpetrators.[24]

MW and HK independently examined the titles and abstracts of articles resulting from these searches, plus

relevant references cited in these articles, with any disagreements resolved by ARH. We excluded articles that met the following criteria: did not concern human health; did not focus specifically on mental health as a main outcome measure; did not collect and analyse primary or secondary data; did not feature a climate change variable as a primary predictor and a mental health variable as a primary outcome; were policy briefs, systematic reviews, commentaries, or clinical reviews without a substantial focus on data analysis (although these were consulted for background information); or were in non-peer-reviewed publications. Abstracts were excluded as they did not contain sufficiently detailed descriptions of methods. Because our focus was on large-scale datasets, we restricted studies to those with more than 500 participants. This cutoff was chosen for three main reasons: large samples yield estimates of effects with high precision and provide the power to detect small effects (such as in climate change studies);[25] a sample size of 500 was considered to be the lower end of what would allow analysis of subgroups;[26] and requiring at least 500 participants would reduce the number of survey studies that were extremely specific in scope (eg, one town) that did not necessarily generalise well or capture larger-scale trends. If articles used the same dataset in multiple papers, we included the most comprehensive of the articles that met these criteria.

Data were extracted independently by two reviewers (any of MW, HK, ARH, or DNC) in a standardised spreadsheet. Extracted information consisted of: overall study design; data source; research question; type of climate event and mental health outcome addressed; sample size, characteristics, and setting; analytical methods; results; and strengths and limitations of the study. We compared our findings, and incongruencies were discussed or resolved with a third reviewer. The Newcastle Ottawa Assessment Scale was used independently by two reviewers (any of MW, HK, ARH, or DNC) to rate quality of the studies; findings were compared for consistency, with a third reviewer available to discuss or resolve differences.[27]

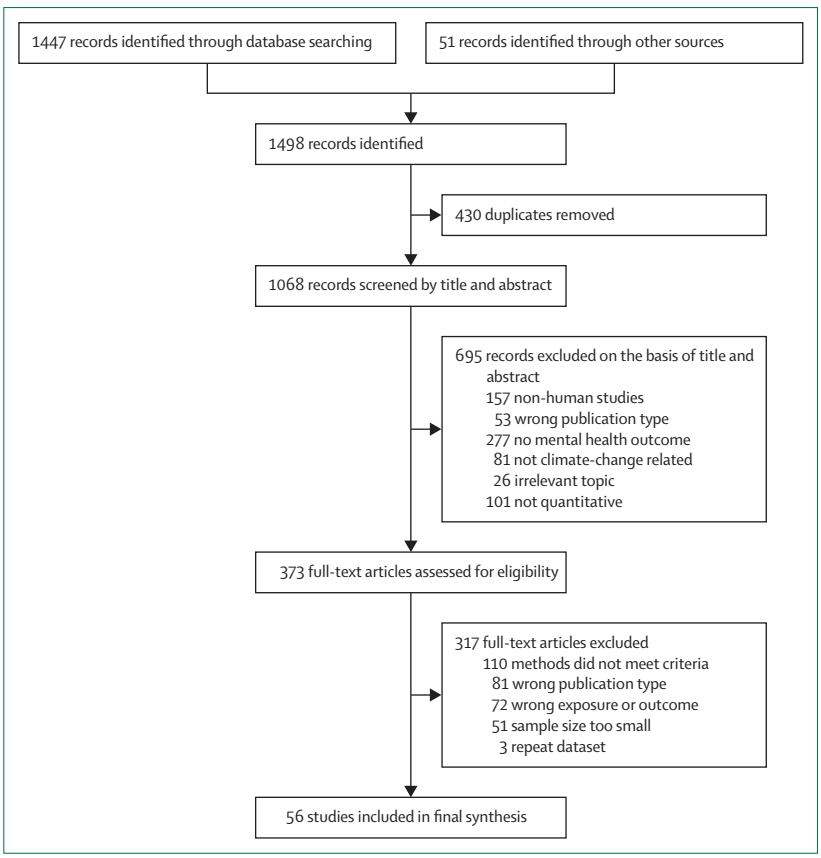

Figure: **PRISMA flow chart for scoping review on climate change and mental health research methods and gaps**
PRISMA=Preferred Reporting Items for Systematic reviews and Meta-Analyses.

Results

The initial search yielded 1498 documents, of which 430 were duplicates, leaving 1068 documents that were screened for relevance (figure). Of these, 695 were excluded, resulting in 373 being considered for a full-text review. From these, 317 were excluded due to not meeting methodological criteria, being the wrong publication type, having wrong exposure or outcome, not having a big enough sample, or using a repeat dataset. The remaining 56 articles were included in the final synthesis (table 1; appendix p 4).

Sample size, participant characteristics, and setting

There were 18 individual countries represented, with 28 (50%) of 56 studies coming from the USA[20,28–43] and Australia.[44–54] 11 (20%) studies came from China,[55–58] the UK,[59–62] and Canada.[63–65] Two (4%) studies focused on Europe[66] and all world countries.[67]

Across studies, two (4%) focused on children and adolescents,[35,55] and one (2%) on people older than 60 years.[28] Sample sizes for individuals ranged from 571[34] to 4 120 514 individuals (over a 10-year period).[43] Other samples included aggregate census tracts,[40] a city,[20] and tweets.[41,42]

Research questions addressed in the articles

51 (91%) of the 56 articles focused on the direct effects of climate change on mental health (with some articles addressing both direct and indirect effects). In 25 (45%) studies, direct effects included self-reported general psychological distress, anxiety, depression, and post-traumatic stress disorder (PTSD) symptoms following a natural disaster.[19,26–28,30–32,35,38,40,42,44–48,50,55,57–59,61,68–70] 16 (29%) studies examined hospital admissions for mental health conditions in the setting of increasing temperatures and during heat waves.[36–38,43,52,56–58,64,65,71–76] 17 (30%) studies analysed changes in rates of suicide, accidental overdose, or mortality among individuals with pre-existing mental illnesses, as associated with temperature and other weather variables such as humidity, precipitation, and wind.[39,41,43,54,61–63,66–70,77–81]

	N (%)
Data source	
Survey	23 (41%)
Electronic health records and administrative claims data	17 (30%)
National and local public health data	17 (30%)
Social media data	2 (4%)
Population	
Adults	18 (32%)
Children	2 (4%)
Both	36 (64%)
Generalisability	
Convenience sample	5 (9%)
Probability-based sample	17 (30%)
Hospital-based sample or catchment area	17 (30%)
Whole population	15 (27%)
Outcome variable	
General psychological distress, depressive, anxiety or trauma symptoms	25 (41%)
Utilisation (emergency care visits, admissions) of MH resources	19 (34%)
Premature mortality (eg, suicide, overdose)	17 (30%)
Violence rates	3 (5%)
Moderator analysis	
Individual-level demographics (eg, age, sex, or socioeconomic status)	56 (100%)
Additional individual-level variables (eg, economic hardship or coping skills)	14 (25%)
Community-level variables (eg, unemployment rates, gun control policy, or availability of psychotropics)	5 (9%)
Symptom or diagnosis type	
General psychological distress, well-being, mental health difficulties, dysphoria	17 (30%)
Anxiety	15 (27%)
Depression	19 (34%)
PTSD	14 (25%)
Bipolar disorder and mania	10 (18%)
Psychosis	9 (16%)
Dementia	7 (13%)
Substance use	10 (18%)
Suicidal thoughts and behaviours	7 (13%)
Death by suicide	14 (25%)
(Table 1 continues in next column)	
(Continued from previous column)	
Exposure type	
Acute (eg, hurricanes or floods)	17 (30%)
Subacute (eg, drought)	8 (14%)
Chronic (eg, changes in ambient temperature)	32 (57%)
Timeframe of outcomes evaluated	
Short term (<1 year post-exposure)	33 (59%)
Medium term (1–5 years post-exposure)	3 (5%)
Long term (>5 years) or ongoing exposure	21 (38%)
Location	
North America	20 (36%)
Australasia	13 (23%)
Europe	11 (20%)
East Asia, south Asia, or southeast Asia	11 (20%)
All countries	1 (2%)
Study setting	
Urban	11 (20%)
Rural	5 (9%)
Both	40 (71%)
Study type	
Cross-sectional	13 (23%)
Retrospective	37 (66%)
Case-control or case-crossover	4 (7%)
Prospective	2 (4%)
Analysis type	
Descriptive analysis	2 (4%)
Standard inferential analysis (eg, *t* tests, χ^2 tests, bivariate and multivariate regression, proportional hazards)	46 (82%)
Additional techniques (eg, distributed lag models, advanced sentiment analysis, Monte Carlo simulations, difference-in-differences, Bayesian modelling, spatial analysis, principal components analysis)	12 (21%)
Predictive (eg, forecasting)	1 (2%)

Some studies used more than one method, so columns may sum to more than 100%. PTSD=Post-traumatic stress disorder.

Table 1: **Summary of scoping review results**

Six (11%) articles examined indirect effects of climate change on mental health. These effects included perceptions of global warming and associated dysphoria, community-level migration, and the relationship between economic hardship due to drought and suicide rates.[44,47,51,66,70,82]

Overall study design and data collection methodology

The 56 articles used four primary data collection methods for measuring mental health outcomes (with some studies using multiple methods): 23 (41%) studies used surveys,[20,28–35,43–51,55,59,60,82,83] 17 (30%) used electronic health records and administrative claims,[36–38,43,52,53,56–58,63–65,71–75] 17 (30%) used national public health data,[39–41,43,54,61,62,66–70,77–81] and two (4%) used social media data.[41,42]

Among studies using survey data, two methodologies were used: original survey data, which typically collected responses of individuals affected by an extreme weather event, and secondary data analyses of population-based surveys. The original survey studies captured responses soon after the weather event, such as immediately following a hurricane, and reflected acute effects on mental health.[28–31,34,35,49,55,82,83] In some cases, multiple follow-up surveys were conducted using a cohort panel, such as 8 and 20 months after Hurricane Katrina, to detect changes in trauma-related symptoms over time.[31]

Secondary data analysis studies analysed responses from publicly available population-based panel surveys or shorter-term longitudinal cohort surveys.[20,32,33,43–48,50,51,59,60] Panel surveys included the US Behavioral Risk Factor

Surveillance System,[20,43] the Household, Income, and Labour Dynamics in Australia Survey,[48] and England's Adult Psychiatric Morbidity Survey.[59] Shorter-term longitudinal cohort studies using survey data were the Australian Rural Mental Health Study, and the 45 and Up cohort study of residents in New South Wales, Australia.[44,46] These survey methods used stratified random sampling within a subset of the population, such as among rural residents or adults older than 45 years.

Studies that used electronic health records or administrative claims to identify mental health outcomes are grouped together methodologically because some countries have single payer systems with linked databases.[36–38,43,52,53,56–58,63–65,71–75] Studies that gathered data from national or local public health sources included vital statistics, crime reports, and World Bank indicators.[39,40,41,54,61,62,66–70,77–81] The two papers using social media data both analysed Twitter content.[41,42]

Study types included cross-sectional (13 [23%] of 56 studies),[28–30,34,42,48–50,55,59,63,82,83] retrospective (37 [66%]),[20,32,35–41,43,44,46,51–54,56,58,60–62,64–68,70–73,75,77–81] case-control or case-crossover (four [7%]),[45,47,57,69] and prospective (two [4%])[31,33] approaches. Longitudinal studies analysed time periods of up to 257 years.[78] Overall, 20 (36%) articles were rated as high quality, 24 (43%) as medium quality, and 12 (21%) as low quality. Issues that stood out in low quality studies included potential representativeness or selection bias (eg, non-probability sampling), ascertainment bias (eg, self-reported diagnosis, unclear proximity to climate event), and absence of comparability (eg, no pre-exposure comparison).

Climate event exposure

The most common climate variable investigated, in 33 (59%) of 56 studies, was change in ambient temperature (minimum, mean, and maximum, or most frequently by month).[19,29,34,36,37,39,41,43,49,51–56,59,60,62–66,68,71–76,79–81] 17 (30%) studies examined mental health following acute events such as hurricanes,[20,28–31,33,42] floods,[51,55,59,60,63] typhoons,[82] dust storms,[79] and heat waves.[52,57,61] Eight (14%) studies investigated subacute events, including drought and the associated effects on farming productivity.[44,45,47–51,54] Four (7%) other studies considered long-term changes in humidity, precipitation, hours of sunshine, wind, air pollution, and noise pollution.[20,32,35,46] In addition, one (2%) study assessed perceived changes in the environment.[34]

Mental health outcomes

In surveys, mental health was measured through self-reported ratings for: general psychological distress; symptoms of depression, anxiety, and PTSD; resilience; and ability to adapt. The most common instruments (reported in seven [13%] of 56 articles) used to screen for mental health disorders were the Patient Health Questionnaire (either PHQ-2 or PHQ-9) for depression, General Anxiety Disorder Scale (either GAD-2 or GAD-7) for anxiety, or the Posttraumatic Stress Disorder Checklist for PTSD.[29,30,33,34,59,60,82] The most common instrument for measuring general distress, reported in seven (13%) studies, was the Kessler Psychological Distress Scale (either K10 or the briefer K2 and K6 versions), a measure of non-specific psychological distress often used in acute trauma studies.[31,44–46,48,49,84] The Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders was also used for psychometric ratings that corresponded to diagnostic criteria (two [4%] studies).[28,31] Two (4%) studies collected self-reported measures of mental health service use.[45,46] One (2%) study asked parents to rate their children's behaviour to detect changes in externalising behaviours,[35] whereas another study (2%) assessed resilience and coping skills using validated scales.[29]

Administrative data sources (17 [30%] studies) were used to identify emergency room visits or inpatient hospital admissions for dementia, depression, mania, bipolar disorder, schizophrenia, inflicted injury or homicide, self-harm, substance use, and suicidal thoughts and behaviours.[36–38,43,52,53,56–58,64,65,71–76] Primary diagnosis was identified using International Classification of Diseases codes.[85] One (2%) study used administrative records to examine referrals to mental health services following floods and fires.[63]

The mental health outcomes in public health data included suicide rates (13 [23%] studies),[41,43,54,61,67,67–70,77–81] fatal accidental drug overdoses (one [2%]),[39] and World Bank or local police reports to measure violence and crime (two [4%]).[40,66] One (2%) study also evaluated changes in mortality rates for people with diagnoses of psychosis, dementia, and substance use disorders.[62] Social media data (two [4%]) was analysed for emotional content, such as sadness, disgust, or fear expressed in Twitter feeds.[41,42]

Although this scoping review focused on methods, we describe the overall findings along with key points. Due to the heterogeneity of analytical methods, geographical regions, time periods, exposures, and outcomes, we did not conduct a meta-analysis of results. Survey-based studies largely found increased distress, anxiety, and depressive symptoms following acute and subacute climate events. Several studies also examined the duration of symptoms: Kessler and colleagues[31] reported ongoing high prevalence of widespread hurricane-related mental illness nearly 2 years after Hurricane Katrina, and Mulchandani and colleagues[60] identified continued elevated rates of psychiatric morbidity in individuals 3 years after experiencing a flooding event compared with a control group, despite an overall reduction in symptoms. A few studies also highlighted protective factors, such as resilience and coping skills for attenuating the effects of a hurricane on depressive symptoms,[29] and living in a neighbourhood with a high amount of green space diminished the association between increasing temperatures and aggression in children and adolescents.[35]

	Research aims	Strengths	Limitations
Original survey	To identify self-reported mental health effects associated with acute and subacute climate events	Captures mental health effects of acute climate events; can tailor to specific locations, climate events, and outcome variables; can use probability sampling	Poor generalisability for non-probability samples; usually small sample sizes; expensive and burdensome to implement; often cross-sectional and without longitudinal data; self-reporting is subject to bias; variability in depth of analysis based on data or as conducted by authors
Panel survey (secondary data)	To examine the longitudinal (or over a broad geographical region) relationship between climate events and self-reported mental health outcomes	Population-based; rigorously monitored and organised; publicly available	Not necessarily linked to specific climate events; data often purposefully deidentifies the location of the respondent
Administrative records (electronic health and claims data)	To evaluate changes in mental health service use that is associated with climate events	Large sample sizes available; longitudinal data available; diagnostic information based on clinical evaluation; can link encounter date to climate event timing	Records might contain incomplete information; only captures service users; inpatient admissions might vary according to extrinsic factors (eg, insurance, bed availability); cannot reliably measure treatment outcomes or psychosocial factors
Public health data	To examine changes in morbidity and mortality data (eg, rates of death by suicide) associated with climate events	Large sample sizes; longitudinal data available (several decades or more); publicly available; whole population data; useful for studying rare events like suicide	Difficult to link climate event timing and mental health outcome together; deidentified data might mean that spatial analysis is not possible; low granularity in location, timing, and specifics of outcome; potential miscategorisation of suicide and overdoses
Social media data	To evaluate a new data type reflecting the emotions or sentiments associated with climate events	Large sample sizes available; allows for detection of subclinical presentations or features; could help to identify and characterise climate-related emergent properties of mental health problems	Select subset of population uses social media; requires advanced analytical techniques; it is unclear how content aligns with psychiatric symptoms or clinical presentations

Table 2: **Scoping review findings: research aims, strengths, and limitations**

Most studies of emergency care and hospital admissions for mental health conditions found increased admission rates during periods of elevated temperatures (especially during heat waves), adjusting for season and historical temperatures. Most studies on death by suicide found increased suicide rates were associated with rising temperatures. Carleton[70] suggested economic hardship as a potential mechanism for the temperature–death by suicide relationship; across 47 years of death by suicide records and climate data in India, suicide rates increased with high temperatures only during the growing season, when heat also reduced crop yields. Helama and colleagues[78] identified an increase in rates of death by suicide associated with rising temperature in Finland over 100 years, until the launch of a nationwide suicide prevention programme, which led to a decline in suicide rates despite ongoing warming temperatures.

By analysing over 6 million tweets from US metropolitan areas to detect depressive language, Burke and colleagues[41] found that each additional 1° Celsius increase in temperature increased the likelihood that a tweet had depressive content. Gruebner and colleagues[42] also analysed tweets in the 11 days before and after Hurricane Sandy, identifying sadness as the most prominent emotion after the disaster.

Discussion

This scoping review highlights the strengths and weaknesses of existing approaches to researching the effects of climate change on mental health. The studies mainly come from high-income countries, particularly the USA and Australia, where effects might not be generalisable to low-income and middle-income settings. There were no studies from South American or African countries (other than one article on all world countries). The inherent characteristics of the methods used (largely retrospective, or observational) limit the ability of these studies to make definitive causal claims about the relationship between climate change and mental health outcomes.

The primary mental health outcomes studied were psychological distress in surveys, emergency room and hospital admissions for a psychiatric disorder in administrative records, and death by suicide in public health data. Whereas nearly a quarter of papers focused on death by suicide, few examined the association of suicidal thoughts and behaviours or changes in substance use with climate events. Additionally, measures of positive aspects of the relationship between climate change and mental health were rarely included. This finding could, however, be reflective of the search terms that focused on psychiatric diagnoses and symptoms. Search terms such as altruism, post-traumatic growth, and sense of meaning might contribute to a richer understanding of how climate change can yield protective factors for mental health or increase resilience.

Data collection methods: strengths and weaknesses

Strengths and weaknesses of the four major data collection methods (surveys, administrative records, public health data, and social media) are summarised (table 2). Most original surveys were cross-sectional and therefore captured only immediate mental health effects following an extreme weather event. Panel surveys were population based, rigorously monitored and organised, and publicly available, but were not necessarily linked to specific climate events. National public health survey data might not include the interview date and often purposefully de-

identifies the location of respondent, precluding their use for short-term exposure analysis. There are some notable exceptions, such as Obradovich and colleagues' study,[20] which mapped national weather data onto Behavioral Risk Factor Surveillance System responses to examine the associations between mental health difficulties and 30-day meteorological exposure, multiyear warming, and acute exposure to natural disasters.

Using clinical records (electronic health records or claims data) has the advantage of capturing large numbers of people in a catchment area, which allows researchers to focus on areas with climate events. These data contain clinically validated psychiatric diagnoses and can be analysed longitudinally. In many cases, hospital admission or emergency room visit data can be indexed by exact date, allowing precision in ascertaining the timing of exposures and outcomes. However, clinical records have notable limitations in reliably capturing the severity of illness and treatment outcomes, and lifestyle behaviours and psychosocial factors.[86,87] Finally, these data might not reflect subclinical symptoms and could exclude people who are less connected to health-care services.

National or global public health datasets provide publicly available, whole population statistics that allow researchers to compare countries, such as Fountoulakis and colleagues'[67] study of the rates of death by suicide across Europe and their association with temperature change. This scale of data is useful for rare events like suicide that might require large sample sizes to reliably detect trends. However, miscategorisation is common for death by suicide and fatal drug overdoses due to variability in how deaths due to suicide are reported and tracked across time and country. Quality of suicide data can vary by region and can lack the granularity to geographically locate the site of death and the changing climate variables. Thus, causal attribution of climate change on these outcomes might not be supported.

Social media data are free, not limited to patients with known mental health conditions, and reflect a more general sample of the population than electronic health records.[88] Analytical techniques can detect themed content, such as sad, hopeless, or despairing emotions around a climate event—a data type that is not otherwise represented in traditional sources. Yet geolocation data are rarely available, and how distress measured via social media corresponds to other metrics of mental health is not clear. Additionally, the population using social media is not fully representative of the general public; for example, 44% of individuals aged 18–24 years in the USA use Twitter compared with 7% of adults aged 65 years and older.[89]

Key gaps and future directions

This scoping review of climate change–mental health research methodology underscores the need for future studies to focus more on databases (both nascent and established) available for researchers and on developing analytical methods that can help to establish a causal link between changing climate patterns and mental health symptoms (panel). Most previous quantitative studies have relied on surveys, often conducted immediately following an extreme weather event. Additional secondary data analyses matched with localised weather data will be important for obtaining valid causal inferences. National health survey agencies will need to increase researcher access to data variables that are often scrambled for deidentification purposes, thereby losing key time and place variables. Specifically, linking residential location, clinical mental health outcomes, and climate data with granular date information will be crucial for moving the field forward.

Across the literature, there was no consensus approach on how to measure the mental health effects of climate change, with measured outcomes ranging from psychological distress to suicide. Consistent, robust measures across studies with common terminology and metrics for climate and mental health outcomes will allow for meaningful summaries and meta-analyses.

The US National Institute of Mental Health Research Domain Criteria (RDoC) could offer a template for assessing psychological and biological dysfunction in the setting of climate change, particularly given that physical

***Panel:* Climate change and mental health research methods: crucial findings**

Gaps

- Varying definitions, study design, data collection methods, and analytical approaches shaped the research questions and findings around climate change and mental health; results should be considered preliminary due to the heterogeneity of methods
- Few studies examined indirect effects of climate change on mental health and associated disparities, particularly for individuals with pre-existing mental illness
- Little work has assessed the effect of climate change on paediatric mental health outcomes or on substance use-related outcomes
- Studies have focused largely on individual mental health effects rather than community-level effects

Future directions

- There is a need for consistent, robust measures of climate events, geographical units of analysis, and mental health outcomes across studies
- More work is needed to evaluate amplifier effects of climate change on mental health contributing to disparities
- Future research is needed to understand how climate change could affect developmental trajectories and related mental health outcomes
- Further studies of climate change and community-level mental health outcomes can inform the development of public mental health interventions, systems planning, and policy

and mental health response systems are so prominently linked in response to extreme weather.[90] RDoC offers a framework for investigating mental disorders that integrates dimensions of functioning, from genomics to behaviour. This framework could provide a useful foundation for further refining the conceptual model of climate change's effects on mental health and building a climate change–mental health behavioural assessment method across domains.

This scoping review also revealed few studies addressing public mental health interventions for climate change. Population-level approaches are needed to understand factors such as public policy response (eg, increased or decreased funding for mental health services and how this affects outcomes following a weather event); epidemiological surveillance and monitoring following weather events (eg, tracking mental health outpatient and crisis services utilisation); community-based preparation and response efforts; and mental health training for health-care providers and first responders. This systems perspective can better account for the widespread effects of climate change across the numerous sectors (eg, environmental, social, or economic) involved in the development, exacerbation, and management of mental health problems.[91]

Future research is also needed to understand the unequal effects of climate change on the mental health of vulnerable and marginalised groups to inform better prevention, planning, response, and adaptation tools and efforts. A health equity perspective must be prioritised to address the interactions between climate change and other social and environmental determinants of health.[10] There is a need to better understand how climate events affect people with pre-existing mental health conditions or those who are predisposed to mental health conditions, the very populations seen in and around the margins of psychiatric services. Even though the detrimental effects of climate change are expected to fall heavily on low-income and middle-income countries, most studies are conducted by researchers from and focus on higher income countries. This major gap in knowledge and expertise will need to be addressed through cross-national partnerships and must be supported by global organisations.

Furthermore, studying epigenetic phenomena around weather events and development will be crucial for understanding the long-term mental health consequences of climate change. For example, there is an emerging body of work on the effects of extreme heat on perinatal health for both mothers and infants.[92] Further studies on the subsequent developmental trajectories and psychiatric outcomes would require longitudinal data that follows offspring over many years.

More than half of the studies were not designed or conducted by mental health researchers or published in mental health journals, which might point to a gap between research on climate change and meaningful clinical applications. Mental health researchers can play a key role in leading or collaborating on research that focuses on climate change and mental health, including helping to select rigorous and appropriate research methodologies that can effectively respond to clinically relevant hypotheses. A robust assessment of mental health symptoms and classification of subclinical and clinical outcomes with appropriate comparison populations can improve the quality of future studies. To prepare the next generation of mental health researchers, residencies and fellowships must mentor trainees to study climate change and psychiatric outcomes.

Limitations

Despite the rigorous screening and selection process, this scoping review might not have captured every eligible paper given the broad interdisciplinary field covered. The searched databases were largely health and medical related, although relevant papers were also found in economics and environmental science journals. We focused on publications in peer-reviewed journals and not grey literature, which could have omitted some meaningful publications. Because this review limited criteria to large-scale datasets, the final set of studies over-represents countries with well established health-care database systems. Furthermore, the language and publication date restrictions mean that this review might not encompass the full global body of published large-scale data analyses on climate change and mental health. The search terms focused heavily on diagnoses and symptoms relevant to psychiatric care, which might have missed work on more holistic definitions of psychological wellbeing. Finally, although this scoping review focused on large-scale data, examining qualitative and small-scale quantitative methodologies would also be a worthwhile endeavour for understanding the scope of research approaches.

Conclusion

The future of research on the effect of climate change on mental health is vast, with the need to develop more nuanced and replicable methodologies and understand the risk of developing mental illness due to both acute and chronic climate change. Without a clear understanding of the research approaches used to clarify the relationship between climate change and mental health, it is difficult to effectively prevent, prepare for, and respond to the mental health needs that arise due to climate events. Insufficient understanding of the problem could lead to long-term unmet needs in physical functioning, mental health functioning, educational attainment, and economic productivity. The relationship between climate change and mental health therefore must be designated as a priority for research and public health attention, and mental health researchers must be prepared to help guide this work.

Contributors

ARH, AG, JA, DC, and WMC helped with conceptualisation of the article.

ARH, MW, HK, and DNC conducted the literature search, screening, and data extraction. ARH and AG drafted the manuscript. All authors contributed to reviewing and editing the manuscript. ARH, MW, and HK accessed and verified the articles in the review. The findings and conclusions of this study are those of the authors and do not necessarily reflect the views of the American Psychiatric Association, US Department of Health and Human Services, or the National Institute on Drug Abuse of the US National Institutes of Health.

Declaration of interests

ARH receives funding from the American Psychiatric Association Foundation. JA has received research funding unrelated to this work from Otsuka Pharmaceuticals and Axsome Therapeutics; editorial fees from Belvoir Publishing; and speaker's fees from the Massachusetts General Hospital Psychiatry Academy and Nevada Psychiatric Association. DC served on the Mental Health Landscape Project Advisory Panel for RAND Corporation, a project funded by Otsuka Pharmaceuticals that is unrelated to this work. WMC reports ownership of stock in General Electric, 3M, and Pfizer, unrelated to the submitted work. All other authors declare no competing interests. The funders above had no role in study design, data collection, data analysis, data interpretation, writing of the report, or the decision to submit the paper for publication. All authors had full access to the data in the study and final responsibility for the decision to submit for publication.

Acknowledgments

We thank Emily Kuhl for assistance with editing, Laura Thompson for administrative support, and the American Psychiatric Association Council on Research for their feedback and comments.

References

1 Watts N, Amann M, Ayeb-Karlsson S, et al. The *Lancet* Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *Lancet* 2018; **391:** 581–630.
2 Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. *Int J Ment Health Syst* 2018; **12:** 28.
3 Berry HL, Bowen K, Kjellstrom T. Climate change and mental health: a causal pathways framework. *Int J Public Health* 2010; **55:** 123–32.
4 Bourque F, Willox AC. Climate change: the next challenge for public mental health? *Int Rev Psychiatry* 2014; **26:** 415–22.
5 Burke SEL, Sanson AV, Van Hoorn J. The psychological effects of climate change on children. *Curr Psychiatry Rep* 2018; **20:** 35.
6 Cianconi P, Betrò S, Janiri L. The impact of climate change on mental health: a systematic descriptive review. *Front Psychiatry* 2020; **11:** 74.
7 Dumont C, Haase E, Dolber T, Lewis J, Coverdale J. Climate change and risk of completed suicide. *J Nerv Ment Dis* 2020; **208:** 559–65.
8 Evans GW. Projected behavioral impacts of global climate change. *Annu Rev Psychol* 2019; **70:** 449–74.
9 Fernandez A, Black J, Jones M, et al. Flooding and mental health: a systematic mapping review. *PLoS One* 2015; **10:** e0119929.
10 Hayes K, Blashki G, Wiseman J, Burke S, Reifels L. Climate change and mental health: risks, impacts and priority actions. *Int J Ment Health Syst* 2018; **12:** 28.
11 Stanke C, Murray V, Amlôt R, Nurse J, Williams R. The effects of flooding on mental health: outcomes and recommendations from a review of the literature. *PLoS Currents* 2012; **30:** e4f9f1fa9c3cae.
12 Padhy SK, Sarkar S, Panigrahi M, Paul S. Mental health effects of climate change. *Indian J Occup Environ Med* 2015; **19:** 3–7.
13 Doherty TJ, Clayton S. The psychological impacts of global climate change. *Am Psychol* 2011; **66:** 265–76.
14 Albrecht G, Sartore GM, Connor L, et al. Solastalgia: the distress caused by environmental change. *Australas Psychiatry* 2007; **15** (suppl 1)**:** S95–98.
15 Helm SV, Pollitt A, Barnett MA, Curran MA, Craig ZR. Differentiating environmental concern in the context of psychological adaption to climate change. *Glob Environ Change* 2018; **48:** 158–67.
16 McMichael A. Climate change and the health of nations: famines, fevers, and the fate of populations. Oxford: Oxford University Press, 2017.
17 Ramin B, Svoboda T. Health of the homeless and climate change. *J Urban Health* 2009; **86:** 654–64.
18 St Louis ME, Hess JJ. Climate change: impacts on and implications for global health. *Am J Prev Med* 2008; **35:** 527–38.
19 WHO. Operational framework for building climate resilient health systems. June 10, 2015. https://www.who.int/publications/i/item/operational-framework-for-building-climate-resilient-health-systems (accessed Dec 20, 2020).
20 Obradovich N, Migliorini R, Paulus MP, Rahwan I. Empirical evidence of mental health risks posed by climate change. *Proc Natl Acad Sci USA* 2018; **115:** 10953–58.
21 Tunstall S, Tapsell S, Green C, Floyd P, George C. The health effects of flooding: social research results from England and Wales. *J Water Health* 2006; **4:** 365–80.
22 Bathiany S, Dakos V, Scheffer M, Lenton TM. Climate models predict increasing temperature variability in poor countries. *Sci Adv* 2018; **4:** eaar5809.
23 Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018; **169:** 467–73.
24 Thornicroft G. People with severe mental illness as the perpetrators and victims of violence: time for a new public health approach. *Lancet Public Health* 2020; **5:** e72–73.
25 Fraley RC, Vazire S. The N-pact factor: evaluating the quality of empirical journals with respect to sample size and statistical power. *PLoS One* 2014; **9:** e109019.
26 Martinez-Mesa J, Gonzalez-Chica D, Bastos J, Bonamigo R, Duquia R. Sample size: how many participants do I need in my research? *An Bras Dermatol* 2014; **89:** 609–15.
27 Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol* 2010; **25:** 603–05.
28 Acierno R, Ruggiero KJ, Kilpatrick DG, Resnick HS, Galea S. Risk and protective factors for psychopathology among older versus younger adults after the 2004 Florida hurricanes. *Am J Geriatr Psychiatry* 2006; **14:** 1051–59.
29 Bistricky SL, Long LJ, Lai BS, et al. Surviving the storm: avoidant coping, helping behavior, resilience and affective symptoms around a major hurricane-flood. *J Affect Disord* 2019; **257:** 297–306.
30 Fullerton CS, McKibben JBA, Reissman DB, et al. Posttraumatic stress disorder, depression, and alcohol and tobacco use in public health workers after the 2004 Florida hurricanes. *Disaster Med Public Health Prep* 2013; **7:** 89–95.
31 Kessler RC, Galea S, Gruber MJ, Sampson NA, Ursano RJ, Wessely S. Trends in mental illness and suicidality after Hurricane Katrina. *Mol Psychiatry* 2008; **13:** 374–84.
32 Noelke C, McGovern M, Corsi DJ, et al. Increasing ambient temperature reduces emotional well-being. *Environ Res* 2016; **151:** 124–29.
33 Pietrzak RH, Tracy M, Galea S, et al. Resilience in the face of disaster: prevalence and longitudinal course of mental disorders following hurricane Ike. *PLoS One* 2012; **7:** e38964.
34 Temte JL, Holzhauer JR, Kushner KP. Correlation between climate change and dysphoria in primary care. *WMJ* 2019; **118:** 71–74.
35 Younan D, Li L, Tuvblad C, et al. Long-term ambient temperature and externalizing behaviors in adolescents. *Am J Epidemiol* 2018; **187:** 1931–41.
36 Basu R, Gavin L, Pearson D, Ebisu K, Malig B. Examining the association between apparent temperature and mental health-related emergency room visits in California. *Am J Epidemiol* 2018; **187:** 726–35.
37 Parker GB, Hadzi-Pavlovic D, Graham RK. Examining for any impact of climate change on the association between seasonality and hospitalization for mania. *J Affect Disord* 2017; **208:** 431–35.
38 Wei Y, Wang Y, Lin CK, et al. Associations between seasonal temperature and dementia-associated hospitalizations in New England. *Environ Int* 2019; **126:** 228–33.
39 Bohnert ASB, Prescott MR, Vlahov D, Tardiff KJ, Galea S. Ambient temperature and risk of death from accidental drug overdose in New York City, 1990–2006. *Addiction* 2010; **105:** 1049–54.
40 Mares D. Climate change and levels of violence in socially disadvantaged neighborhood groups. *J Urban Health* 2013; **90:** 768–83.
41 Burke M, Gonzalez F, Baylis P, et al. Higher temperatures increase suicide rates in the United States and Mexico. *Nat Clim Chang* 2018; **8:** 723–29.

42 Gruebner O, Lowe SR, Sykora M, Shankardass K, Subramanian SV, Galea S. A novel surveillance approach for disaster mental health. *PLoS One* 2017; **12:** e0181233.

43 Mullins JT, White C. Temperature and mental health: evidence from the spectrum of mental health outcomes. *J Health Econ* 2019; **68:** 102240.

44 Austin EK, Ley T, Kiem AS, et al. Drought-related stress among farmers: findings from the Australian Rural Mental Health Study. *Med J Aust* 2018; **209:** 159–65.

45 Brew B, Inder K, Allen J, Thomas M, Kelly B. The health and wellbeing of Australian farmers: a longitudinal cohort study. *BMC Public Health* 2016; **16:** 988.

46 Ding N, Berry HL, Bennett CM. The importance of humidity in the relationship between heat and population mental health: evidence from Australia. *PLoS One* 2016; **11:** e0164190.

47 Edwards B, Gray M, Hunter B. The impact of drought on mental health in rural and regional Australia. *Soc Indic Res* 2014; **121:** 177–94.

48 Friel S, Berry H, Dinh H, O'Brien L, Walls HL. The impact of drought on the association between food security and mental health in a nationally representative Australian sample. *BMC Public Health* 2014; **14:** 1102.

49 Hanigan IC, Schirmer J, Niyonsenga T. Drought and distress in southeastern Australia. *EcoHealth* 2018; **15:** 642–55.

50 OBrien LV, Berry HL, Coleman C, et al. Drought as a mental health exposure. *Environ Res* 2014; **131:** 181–87.

51 Powers JR, Loxton D, Baker J, Rich JL, Dobson AJ. Empirical evidence suggests adverse climate events have not affected Australian women's health and well-being. *Aust N Z J Public Health* 2012; **36:** 452–57.

52 Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian city. *Environ Health Perspect* 2008; **116:** 1369–75.

53 Speldewinde PC, Cook A, Davies P, Weinstein P. A relationship between environmental degradation and mental health in rural Western Australia. *Health Place* 2009; **15:** 865–72.

54 Hanigan IC, Butler CD, Kokic PN, Hutchinson MF. Suicide and drought in New South Wales, Australia, 1970–2007. *Proc Natl Acad Sci USA* 2012; **109:** 13950–55.

55 Peng M, Liu A, Zhou J, et al. Association between posttraumatic stress disorder and preflood behavioral characteristics among children aged 7–15 years in Hunan, China. *Medical Princ Prac* 2011; **20:** 336–40.

56 Chan EYY, Lam HCY, So SHW, et al. Association between ambient temperatures and mental disorder hospitalizations in a subtropical city: a time-series study of Hong Kong special administrative region. *Int J Environ Res Public Health* 2018; **15:** e754.

57 Liu X, Liu H, Fan H, Liu Y, Ding G. Influence of heat waves on daily hospital visits for mental illness in Jinan, China—a case-crossover study. *Int J Environ Res Public Health* 2018; **16:** e87.

58 Zhao D, Zhang X, Xie M, et al. Is greater temperature change within a day associated with increased emergency admissions for schizophrenia? *Sci Total Environ* 2016; **566–567:** 1545–51.

59 Graham H, White P, Cotton J, McManus S. Flood- and weather-damaged homes and mental health: an analysis using England's mental health survey. *Int J Environ Res Public Health* 2019; **16:** e3256.

60 Mulchandani R, Armstrong B, Beck CR, et al. The English national cohort study of flooding & health: psychological morbidity at three years of follow up. *BMC Public Health* 2020; **20:** 321.

61 Page LA, Hajat S, Kovats RS. Relationship between daily suicide counts and temperature in England and Wales. *Br J Psychiatry* 2007; **191:** 106–12.

62 Page LA, Hajat S, Kovats RS, Howard LM. Temperature-related deaths in people with psychosis, dementia and substance misuse. *Br J Psychiatry* 2012; **200:** 485–90.

63 Reifels L, Bassilios B, Spittal MJ, King K, Fletcher J, Pirkis J. Patterns and predictors of primary mental health service use following bushfire and flood disasters. *Disaster Med Public Health Prep* 2015; **9:** 275–82.

64 Vida S, Durocher M, Ouarda TB, Gosselin P. Relationship between ambient temperature and humidity and visits to mental health emergency departments in Québec. *Psychiatr Serv* 2012; **63:** 1150–53.

65 Wang X, Lavigne E, Ouellette-kuntz H, Chen BE. Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. *J Affect Disord* 2014; **155:** 154–61.

66 Barlett CP, DeWitt CC, Madison CS, Heath JB, Maronna B, Kirkpatrick SM. Hot temperatures and even hotter tempers: sociological mediators in the relationship between global climate change and homicide. *Psychol Violence* 2020; **10:** 1–7.

67 Fountoulakis KN, Chatzikosta I, Pastiadis K, et al. Relationship of suicide rates with climate and economic variables in Europe during 2000. *Ann Gen Psychiatry* 2012; **15:** 19.

68 Müller H, Biermann T, Renk S, et al. Higher environmental temperature and global radiation are correlated with increasing suicidality—a localized data analysis. *Chronobiol Int* 2011; **28:** 949–57.

69 Sim K, Kim Y, Hashizume M, et al. Nonlinear temperature-suicide association in Japan from 1972 to 2015: its heterogeneity and the role of climate, demographic, and socioeconomic factors. *Environ Int* 2020; **142:** 105829.

70 Carleton TA. Crop-damaging temperatures increase suicide rates in India. *Proc Natl Acad Sci USA* 2017; **114:** 8746–51.

71 Chen NT, Lin PH, Guo YLL. Long-term exposure to high temperature associated with the incidence of major depressive disorder. *Sci Total Environ* 2019; **659:** 1016–20.

72 Linares C, Culqui D, Carmona R, Ortiz C, Díaz J. Short-term association between environmental factors and hospital admissions due to dementia in Madrid. *Environ Res* 2017; **152:** 214–20.

73 Medici CR, Vestergaard CH, Hadzi-Pavlovic D, Munk-Jørgensen P, Parker G. Seasonal variations in hospital admissions for mania: examining for associations with weather variables over time. *J Affect Disord* 2016; **205:** 81–86.

74 Sung TI, Chen MJ, Su HJ. A positive relationship between ambient temperature and bipolar disorder identified using a national cohort of psychiatric inpatients. *Soc Psychiatry Psychiatr Epidemiol* 2013; **48:** 295–302.

75 Williams MN, Hill SR, Spicer J. Do hotter temperatures increase the incidence of self-harm hospitalisations? *Psychol Health Med* 2016; **21:** 226–35.

76 Vida S, Durocher M, Ouarda TB, Gosselin P. Relationship between ambient temperature and humidity and visits to mental health emergency departments in Québec. *Psychiatr Serv* 2012; **63:** 1150–53.

77 Fountoulakis KN, Savopoulos C, Zannis P, et al. Climate change but not unemployment explains the changing suicidality in Thessaloniki Greece (2000–2012). *J Affect Disord* 2016; **193:** 331–38.

78 Helama S, Holopainen J, Partonen T. Temperature-associated suicide mortality: contrasting roles of climatic warming and the suicide prevention program in Finland. *Environ Health Prev Med* 2013; **18:** 349–55.

79 Lee H, Jung J, Myung W, et al. Association between dust storm occurrence and risk of suicide: case-crossover analysis of the Korean national death database. *Environ Int* 2019; **133:** 105146.

80 Preti A, Lentini G, Maugeri M. Global warming possibly linked to an enhanced risk of suicide: data from Italy, 1974–2003. *J Affect Disord* 2007; **102:** 19–25.

81 Santurtún M, Sanchez-Lorenzo A, Del Real Á, Zarrabeitia MT, Santurtún A. Association between suicide and environmental variables in the north of Spain: a 14-year analysis. *Cult Med Psychiatry* 2018; **42:** 647–53.

82 Pollack AA, Weiss B, Trung LT. Mental health, life functioning and risk factors among people exposed to frequent natural disasters and chronic poverty in Vietnam. *BJPsych Open* 2016; **2:** 221–32.

83 Tawatsupa B, Yiengprugsawan V, Kjellstrom T, Seubsman SA, Sleigh A. Heat stress, health and well-being: findings from a large national cohort of Thai adults. *BMJ Open* 2012; **2:** e001396.

84 Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med* 2002; **32:** 959–76.

85 WHO. International statistical classification of disease and related health problems (ICD). https://www.who.int/standards/classifications/classification-of-diseases (accessed Jan 11, 2021).

86 Riley GF. Administrative and claims records as sources of health care cost data. *Med Care* 2009; **47** (suppl 1)**:** S51–55.

87 Casey JA, Schwartz BS, Stewart WF, Adler NE. Using electronic health records for population health research: a review of methods and applications. *Annu Rev Public Health* 2016; **37:** 61–81.

88 Sinnenberg L, Buttenheim AM, Padrez K, Mancheno C, Ungar L, Merchant RM. Twitter as a tool for health research: a systematic review. *Am J Public Health* 2017; **107:** e1–8.

89 Pew Research Center. US adults' social platform use, by demographic group. 2019. https://www.marketingcharts.com/charts/us-adults-social-platform-use-demographic-group-2019/attachment/pew-social-platform-use-by-demographic-apr2019 (accessed Dec 20, 2020).

90 National Institute of Mental Health. Research domain criteria initiative. 2020. https://www.nimh.nih.gov/research/research-funded-by-nimh/rdoc/about-rdoc.shtml (accessed Dec 20, 2020).

91 Coverdale J, Balon R, Beresin EV, et al. Climate change: a call to action for the psychiatric profession. *Acad Psychiatry* 2018; **42:** 317–23.

92 Malaspina D, Howell EA, Spicer J. Intergenerational echoes of climate change. *JAMA Psychiatry* 2020; **77:** 778–80.