Title

A call for the informatics community to define priority practice and research areas at the intersection of climate and health: report from 2023 mini-summit

Authors

Schleyer, Titus
Berenji, Manijeh
Deck, Monica
et al.

Publication Date

2025-03-13

DOI

10.1093/jamia/ocae292

Peer reviewed

Journal of the American Medical Informatics Association, 2025, 1–9
https://doi.org/10.1093/jamia/ocae292
Perspective

Perspective

A call for the informatics community to define priority practice and research areas at the intersection of climate and health: report from 2023 mini-summit

Titus Schleyer, DMD, MBA, PhD[1], Manijeh Berenji, MD, MPH[2,3,*], Monica Deck, BA[1], Hana Chung, MS[4], Joshua Choi, MD[5], Theresa A. Cullen, MD[6], Timothy Burdick, MD[7], Amanda Zaleski, PhD[8], Kelly Jean Thomas Craig, PhD[8], Oluseyi Fayanju, MD[9], Muhammad Muinul Islam, PhD[10]

[1]Center of Biomedical Informatics, Regenstrief Institute/Indiana University, Indianapolis, IN 46202, United States, [2]Department of Environmental and Occupational Health, Wen School of Public Health, Irvine, CA 92697, United States, [3]Division of Occupational and Environmental Medicine, Department of Medicine, UC Irvine School of Medicine, Irvine, CA 92697, United States, [4]School of Information, University of Michigan, Ann Arbor, MI 48104, United States, [5]Department of Medicine, University of Utah Health, Salt Lake City, UT 84132, United States, [6]Pima County, AZ Health Department, Regenstrief/Indiana University Department of Family Medicine, Tucson, AZ 85714, United States, [7]Department of Community and Family Medicine, Dartmouth Health, Lebanon, NH 03756, United States, [8]Clinical Evidence Development, Medical Affairs, CVS Health, Hartford, CT 06156, United States, [9]Department of Clinical Informatics, Stanford Health, Palo Alto, CA 94304, United States, [10]Department of Biomedical Informatics, Biostatistics and Medical Epidemiology, University of Missouri School of Medicine, Columbia, MO 65212, United States

*Corresponding author: Manijeh Berenji, MD, MPH, UC Irvine Department of Environmental and Occupational Health, PO Box 6126, Oxnard, CA 93031, United States (manijehberenji@gmail.com)

Abstract

Objective: Although biomedical informatics has multiple roles to play in addressing the climate crisis, collaborative action and research agendas have yet to be developed. As a first step, AMIA's new Climate, Health, and Informatics Working Group held a mini-summit entitled *Climate and health: How can informatics help*? during the AMIA 2023 Fall Symposium to define an initial set of areas of interest and begin mobilizing informaticians to confront the urgent challenges of climate change.

Materials and Methods: The AMIA Climate, Health, and Informatics Working Group (at the time, an AMIA Discussion Forum), the International Medical Informatics Association (IMIA), the International Academy of Health Sciences Informatics (IAHSI), and the Regenstrief Institute hosted a mini-summit entitled Climate and health: How can informatics help? on November 11, 2023, during the AMIA 2023 Annual Symposium (New Orleans, LA, USA). Using an affinity diagramming approach, the mini-summit organizers posed 2 questions to ∼50 attendees (40 in-person, 10 virtual).

Results: Participants expressed a broad array of viewpoints on actions that can be undertaken now and areas needing research to support future actions. Areas of current action ranged from enhanced education to expanded telemedicine to assessment of community vulnerability. Areas of research ranged from emergency preparedness to climate-specific clinical coding to risk prediction models.

Discussion: The mini-summit was intended as a first step in helping the informatics community at large set application and research priorities for climate, health, and informatics.

Conclusion: The working group will use these perspectives as it seeks further input, and begins to establish priorities for climate-related biomedical informatics actions and research.

Key words: climate change; biomedical informatics; environmental health.

Background

The climate crisis is an alarming global threat to individual and public health. Intensifying climate-related exposures such as extreme weather events, rising sea levels, and temperature fluctuations have direct and indirect implications for human health.[1,2] More frequent heat waves are associated with greater risks of heat-related illnesses ranging from heat exhaustion to heat stroke.[3,4] Furthermore, worsening air pollution is contributing to increasing numbers of cardiopulmonary and pulmonary complications, and rising cardiovascular-related mortality rates.[5,6] Those risks disproportionately impact vulnerable populations such as children, older adults, individuals with chronic conditions, and people without homes.[7,8] Increased occurrence and severity of extreme weather and other events, including hurricanes, floods, droughts, wildfires, and heatwaves, cause direct physical and/or environmental harm, such as injury, displacement, environmental degradation, and saltwater intrusion.[1] Additional long-term sequelae of climate change are numerous, including the spread of vector-borne diseases such as dengue fever and malaria to areas that were previously non-endemic, alongside the emergence of other pathogenic conditions.[9–12] The most

Received: May 8, 2024; **Revised:** November 4, 2024; **Editorial Decision:** November 10, 2024; **Accepted:** November 14, 2024

recent *Lancet* Countdown on Health and Climate Change report presents sobering projections for the health and survival of people worldwide unless "profound and immediate systemic changes" are made.[1] Most notably, the report forecasts a disturbing trajectory in key indicators for global progress, including a 370% increase in heat-related deaths, an additional 525 million individuals facing moderate-to-severe food insecurity, and a ~36% increase in transmission of dengue disease (given a 2°C surface temperature increase scenario) by 2050.

Because understanding and addressing the impact of climate change on human health depend on the collection and analysis of data,[1] interest in the role of biomedical informatics in addressing climate change has also increased. All of the *2023 Lancet* Countdown's "11 priorities to deliver a healthy, thriving future" rely on climate data-informed surveillance, with 4 priorities specifically calling for strengthened global data collection and analysis, capacity to support climate change research, and knowledge generation.[1] However, given its urgency and public health implications, an undertaking of this magnitude necessitates strategic direction and concerted collaboration in the informatics community. This requires involving key stakeholders in biomedical informatics, healthcare providers, public health, policymakers, community leaders, regulatory bodies, technology developers, and others. At the same time, biomedical informaticians have knowledge about the healthcare system and its operations that can be useful in defining ways for the health profession to contribute to climate change mitigation and adaptation strategies.[13]

Methods

As a first step to that end, the AMIA Climate, Health, and Informatics Working Group (at the time, an AMIA Discussion Forum), the International Medical Informatics Association (IMIA), the International Academy of Health Sciences Informatics (IAHSI), and the Regenstrief Institute hosted a mini-summit entitled *Climate and health: How can informatics help?* on November 11, 2023, during the AMIA 2023 Annual Symposium (New Orleans, LA, USA). AMIA is the leading professional association for >5500 multidisciplinary subject matter experts committed to the practice of informatics as it relates to clinical care, research, education, and policy.[14] IMIA seeks to grow and nurture a collaborative global biomedical and health informatics community that encourages and supports international initiatives to improve health for all. IAHSI promotes the dissemination of knowledge and best practices, fosters new ideas, and encourages worldwide collaboration and sharing of expertise and resources, by recognizing those who have made key contributions to biomedical informatics internationally. The primary aims of the mini-summit were to (1) initiate dialogue on the impact of climate change on health in the informatics context, and (2) conduct an open forum to identify potential opportunities, solutions, and collaborations at the intersection of climate, health, and informatics.

Table 1. Attendee professional demographics.

Academia ($n = 40$)	Industry ($n = 10$)
Students	Health IT
Fellows	Insurance carriers
Junior faculty	
Senior faculty	
Department chairs	

In-person participants were registered attendees of the AMIA 2023 Annual Symposium. Virtual attendees were also invited to participate. Participants consisted of informaticians from a wide cross-section of disciplines (biomedical informatics, clinical informatics, public health informatics, and others) including academics of various tenures (junior faculty to senior faculty) and in various roles (department chairs, journal editors, and association presidents), students and fellows (PhD, medical and informatics training programs), as well as industry leaders (Table 1). Using an affinity diagramming approach[15] defined *a priori* (Indiana University IRB Protocol #21183), the mini-summit organizers posed 2 questions to ~50 attendees (40 in-person, 10 virtual). We focused the questions on actions to support *mitigation*, that is, making climate change impacts less severe by preventing or reducing greenhouse gas emissions, and *adaptation*, that is, adjusting to the current and future effects of climate change.[16]

1) *Current action and implementation*: What evidence-based professional practices can individuals, groups, and organizations in healthcare apply or implement *now* to help (1) mitigate or (2) adapt to climate change?
2) *Research*: What research (of any kind) should the informatics community conduct to help the healthcare profession (1) mitigate or (2) adapt to climate change? The findings will then form the basis for evidence-based practices for future action and implementation.

The rationale for posing 2 distinct questions was to identify actions that can be taken *now* while acknowledging that additional approaches and solutions will have to be developed. While we considered the 2 areas as mainly separate, overlap in responses was expected. All responses were recorded by mini-summit organizers (H.C., J.C., M.D., T.S.) and synthesized (M.B., H.C., J.C., M.D., T.S.) to identify current- and future-state priorities for implementation and research.

In this process, we categorized attendees' responses using affinity diagramming, an inductive exercise in which participants individually first record their own points and insights on Post-it™ notes. Then, participants collaborate to sort the Post-it™ notes into groups that have some similarity in intent, problem, or issue. We then labeled each group with a descriptive, summary note, and continued grouping until each cluster of notes was summarized and all comments represented. Affinity diagramming has several benefits. First, it avoids the danger of the most vocal participants dominating the discussion since each attendee records their own ideas independently. Second, popular ideas are easily discerned by the number of Post-it™ notes they are recorded on.

To check the group output against the current literature, we queried PubMed for the terms "climate change" and "informatics" (both Medical Subject Headings)[17] in July 2024. The exact search was: Search: **(climate change) AND (informatics)**

("climate change"[MeSH Terms] OR ("climate"[All Fields] AND "change"[All Fields]) OR "climate change"[All Fields]) AND ("informatics"[MeSH Terms] OR "informatics"[All Fields] OR "informatic"[All Fields] OR "informatization"[All Fields]) **Translations**

climate change: "climate change"[MeSH Terms] OR ("climate"[All Fields] AND "change"[All Fields]) OR "climate change"[All Fields] **informatics:** "informatics"[MeSH Terms] OR "informatics"[All Fields] OR "informatic"[All Fields] OR "informatization"[All Fields]

Two authors, T.S. and M.M., reviewed all citations independently and resolved conflicts jointly.

Results

In response to the current action and implementation question, comments clustered into 11 areas: literacy and education, workforce, regulations and policy, healthcare operations, measurement and evaluation, partnerships, community adaptation and resources, analytics, emergency preparedness, finance, and clinical decision support (Table 2). These responses point to the need for a cohesive yet multi-pronged strategy. With respect to education, participants noted that integrating climate literacy into all aspects of healthcare delivery will require that healthcare professionals gain, through a variety of instructional modes, a fundamental understanding of their individual and collective carbon footprints and other climate change impacts. Workforce development, participants said, will involve educating dedicated climate health experts with cross-disciplinary knowledge and expertise, while creative policymaking will be needed to incentivize climate-friendly practices in the healthcare sector and beyond, leading to optimal resource utilization and sustainability-focused practices. Transforming clinical operations will require reducing travel emissions from both health care practitioners and patients, switching from fossil fuel-generated power to renewable energy sources, minimizing resource use on all levels including essential supplies, and modernizing IT to support climate-friendly clinical and administrative operations. Regarding measurement and evaluation, comments emphasized the need to establish real-time monitoring of immediate and short-term climate impacts and resource utilization in the form of actionable dashboards. Participants also described methodologies for predicting long-term climate impacts via advanced predictive modeling techniques. Multisectoral partnerships across governmental agencies, research institutions, community organizations, and business entities, participants noted, will be crucial in addressing climate change and adaptation/mitigation efforts (including how to address resource allocation to those most in need and how to advance predictive modeling techniques to anticipate future resource needs). Furthermore, emergency preparedness and data stewardship (including IT resilience and health record access during natural disasters, crisis response scenarios, and mass human displacement as a result of climate events) are essential, so that clinical decision support and other informatics tools can guide healthcare providers appropriately.

In response to the research question, participants focused on the following areas: (1) emergency preparedness, (2) cost and carbon footprint, (3) sustainability, and (4) finance (Table 3). We put comments that did not fall into these 4 areas in a miscellaneous category. Two key areas identified for emergency preparedness research were IT resilience (to include evaluation of the current state of backup power solutions, data protection strategies, and alternative communication methods), and minimum necessary health and social determinants data collection and formatting to ensure that information is shared among first responders, clinicians, and other stakeholders. To optimize remote patient monitoring and other virtual medicine platforms, participants noted that more research is needed to define the level of electronic support needed, triage those who need in-person assessment from those who do not, and facilitate interoperability in communication streams. Regarding carbon-related research, comments emphasized the need to develop a systematic framework for information sharing and quantify the carbon benefits of a telemedicine platform for executives who would finance such platforms. From a sustainability and data analytics perspective, integrating the climate health informatics framework into the healthcare informatics framework, enhancing and developing new clinical coding standards, and forming a core set of data elements were seen as priorities.

The literature search yielded 1823 raw citations, dating back to 1989. Of those, 126 focused on climate, health, and informatics. Collectively, the papers had a large degree of overlap with the results of the mini-summit, both for current actions and implementations, as well as research. For instance, multiple papers addressed issues of informatics methods and data[18–26]; sustainability in healthcare,[27–31] sometimes with a focus on informatics/IT applications[30–33]; the role and impact of digital health interventions[34–36]; disaster preparedness[37,38]; public health surveillance[39–42]; measurement and monitoring[29]; and education,[43–45] awareness,[46,47] and communication.[48,49] Ideas from the summit that appeared be additive to the current literature included a strong focus on broad and inclusive collaboration; career pathways for climate-focused healthcare roles; advocating for policy changes and regulation; systematically and comprehensively assessing the carbon footprint of healthcare diagnostics, procedures, therapies, and clinical and administrative workflows; sourcing energy renewably; improving the management of resources and waste, including developing a more resource-conscious culture; designing feedback loops to continuously improve sustainability performance; integrating climate change metrics into existing healthcare performance models; accommodating environmental determinants of health in terminologies and coding systems; focusing on environmental justice and equity; developing more detailed approaches for disaster preparedness, including how to strengthen resilience of IT infrastructures; addressing the financial viability of sustainability and climate action; building climate considerations into clinical decision support and Electronic Health Records (EHRs); and researching consumer expectations. Many ideas generated at the mini-summit were also consistent with the recommendations made by Coiera and Magrabi[50] in a seminal editorial suggesting ten action steps that informaticians can take to address climate change.

Discussion

The mini-summit was intended as a first step in helping the informatics community at large set application and research priorities for climate, health, and informatics. While the recruitment of attendees was non-systematic and largely focused on attendees of the 2023 AMIA Annual Symposium, the generated ideas were largely consistent with the current literature, but also yielded some novel ideas and directions focused on informatics. As a result of discussions at the mini-summit, as well as subsequent discussions within the AMIA Climate, Health and Informatics Working Group, and with

Table 2. Responses on actions and implementations that could be introduced currently.

Area	Action	Implementation
Literacy and education	Increase awareness of climate change impacts	• Locally: Host educational workshops and community events • Regionally: Collaborate with public health agencies and NGOs • Nationally: Advocate for climate education initiatives • Internationally: Support global health partnerships
	Track carbon footprint	• Individual: Assess personal and professional carbon footprint • Healthcare organization: Conduct carbon footprint audits
	Foster climate-friendly choices	• Integrate climate principles into healthcare curricula • Partner with vulnerable communities to co-design educational programs • Offer just-in-time training for climate-related interventions
Workforce	Build a climate-literate workforce	• Upskill existing healthcare professionals in climate science and resilience • Educate future healthcare workers on climate-sensitive care • Create career pathways for climate-focused healthcare roles
Regulations and policy	Incentivize climate-friendly practices	• Advocate for policy changes that reward sustainable healthcare operations • Implement internal policies to encourage green choices (eg, telemedicine, renewable energy) • Design reimbursement models that promote climate-friendly care
	Enhance EHR sustainability	• Develop "green-leafing" features in EHRs to minimize environmental impact • Leverage EHR data for sustainable care insights (eg, reducing high-carbon medications) • Standardize medical device validation and public health data sharing
Healthcare operations	Reduce patient and provider travel	• Promote public transit and bicycle incentives for healthcare providers and patients • Expand telemedicine and virtual care options • Optimize clinical workflows to minimize travel needs
	Source renewable energy	• Invest in on-site renewable energy generation (eg, solar panels) • Purchase and advocate for clean energy from local providers • Track and report progress toward renewable energy targets
	Prioritize resource efficiency	• Reduce dependence on disposables (eg, switch to reusable supplies) • Minimize paper and fax usage (eg, digitize processes) • Implement waste reduction & recycling programs • Extend lifespan of durable medical equipment • Design resource-efficient health IT infrastructure
Measurement and evaluation	Monitor climate impacts	• Implement real-time monitoring systems for resource consumption and emissions • Design feedback loops to continuously improve sustainability performance • Integrate climate change metrics into existing healthcare performance models
Partnerships	Foster cross-sector collaboration	• Build partnerships with environmental organizations, government agencies, and public health departments • Engage with communities most affected by climate change • Collaborate with national EHR vendors and technology providers
Community adaptation and resources	Assess community vulnerability	• Identify populations at increased risk from climate impacts • Develop resource allocation plans based on social vulnerability indices
	Predict resource needs	• Use data analytics to predict climate events and associated resource requirements • Prepare essential resources (eg, cooling centers, medications) for vulnerable populations
Analytics	Optimize clinical and administrative efficiency	• Implement data dashboards to track energy use, resource consumption, and waste production • Leverage analytics to identify opportunities for sustainability improvements
Emergency preparedness	Enhance healthcare resilience	• Conduct vulnerability assessments for healthcare facilities and IT systems • Develop disaster preparedness plans for extreme weather events • Establish protocols for minimum health record access during crisis response • Prepare for mass displacement and refugee situations

(continued)

Table 2. (continued)

Area	Action	Implementation
Finance	Make climate action financially viable	• Demonstrate the cost-savings potential of sustainable healthcare practices • Secure funding and grants for climate-related initiatives • Develop innovative financing models for clean energy investments
Clinical decision support	Encourage climate-friendly choices	• Integrate climate considerations into clinical decision support systems • Develop "nudge" strategies to promote sustainable care options • Educate healthcare providers on the environmental implications of clinical decisions

AMIA leadership, the AMIA Public Policy Committee, and others, we are making the following recommendations:

1) *Leadership in climate, health, and informatics*: The informatics community should continue to build on its early leadership in climate, health, and informatics to advance the important role of biomedical informatics in coping with the climate crisis. Evidence of AMIA's early leadership includes JAMIA's 2021 publication, in parallel with more than 100 health and science journals, of a key editorial[51] that called for emergency action to limit global temperature increases, restore biodiversity and protect health; JAMIA's December 2022 issue focused on climate change; AMIA's approval of its Climate, Health and Informatics Working Group in February of 2024; and the increasing number of submissions to AMIA conferences under the heading of "environmental health and climate informatics." The Working Group co-sponsored the NorCal Symposium on Climate Health and Equity, whose theme is "Climate Health Informatics," during the AMIA 2024 Annual Symposium. Finally, the IMIA Yearbook of Informatics in 2025 will focus on climate and health, and IMIA is in the process of establishing a climate, health, and informatics working group as of this writing.
2) *Partnerships with other efforts at the intersection of climate and health*: Addressing the climate crisis requires broad and collective action. Therefore, it is important that the informatics community partner with other initiatives and organizations, such as the Climate and Health Program of the Centers for Disease Control and Prevention; climate and health policy at the federal government level; the Climate and Health Initiative of the National Institutes of Health; the Center for Climate, Health, and Equity of the American Public Health Association; the National Academy of Medicine's (NAM's) Action Collaborative on Decarbonizing the US Health Sector; the Medical Society Consortium on Climate and Health (MSCCC); and global efforts such as the Planetary Health Alliance and the Global Consortium on Climate and Health Education. AMIA already has joined the NAM and MSCCC initiatives, and the Working Group has built a strong relationship with the Healthcare Information and Management Systems Society.
3) *Connections among scientific and applied communities*: Addressing the climate crisis requires collaboration among many scientific and applied fields. Scientific fields include climate science, environmental science, atmospheric science, environmental engineering, geosciences, agricultural science, urban and regional planning, sociology and human behavior, public health, healthcare, biomedical informatics and communications. Applied fields comprise industrial engineering, business, and economics, among others. However, currently few of those fields pursue the robust and energetic collaboration that we need. Because informatics has a large focus on data and information, it can play a key role in helping connect various domains.
4) *Partnerships with citizen scientists and patient/caregiver-driven climate-focused research communities*: Although scientific and applied communities possess expertise that is critical for a meaningful response to climate-related health concerns, they cannot undertake all needed research and advocacy. Recognition of and engagement with citizen scientists[52,53] and patient/caregiver researchers will advance climate response and resilience by supporting protocol development, data collection, research dissemination, and other efforts.
5) *Policy engagement*: AMIA has a robust public policy program currently focused on 4 priorities: (1) support the healthcare workforce by advancing the field of informatics and reducing the burden on clinicians; (2) advocate for evidence-based care and decision-support through informatics, including through machine-learning and AI; (3) advocate for health IT solutions that ameliorate systemic biases and discrimination; and (4) advocate for ongoing funding for the field, including informatics research. The area of climate, health, and informatics intersects with all of them, and AMIA should integrate climate-relevant considerations with its public policy positions going forward.
6) *Representation, curation, and connection of data and information regarding climate, health, and informatics*: The informatics community has a long and impactful history in helping represent and curate data and information in healthcare and biomedicine.[54] This history should be written forward with regard to climate data. For instance, AMIA could work with the National Library of Medicine and others to ensure that data sets, rapidly growing literature, and practical guidelines, best practices, and implementation approaches are findable, accessible, interoperable, and reusable, in line with the FAIR principles.[55] In addition, in parallel with bridging the gaps among disciplines described above, we also must connect relevant data sets. For instance, to understand the manifestation, impact, and trajectory of

Table 3. Responses on needed types of research and other longer-term actions.

Area	Research focus	Examples
Emergency preparedness	IT Resilience	• Strengthen IT infrastructure against disasters (floods, outages) • Define minimum health and social record for crisis response
	Telehealth Optimization	• Improve virtual consultations to reduce traffic • Optimize telemedicine efficiency and effectiveness • Determine optimal levels of electronic support (text, voice, video)
	Remote Examination Solutions	• Research methods for remote physical exams or assessments • Enhance patient information sharing (images, documents, DICOM files) • Explore the use of templates and structured communication formats
	Clinician Workload Management	• Investigate clinician capacity for multi-patient management (help desk model) • Explore incentives for green transportation options • Optimize clinician and patient commuting
Cost and carbon footprint	Resource and Workflow Assessment	• Compare carbon footprints of healthcare resources, materials, and workflows • Quantify telehealth carbon benefits across different regions • Design climate-conscious health interventions • Categorize and label energy costs throughout asset lifecycles
	Consumer Preferences and Expectations	• Research consumer expectations around virtual care's carbon footprint • Optimize hospital size for minimum climate impact
Sustainability	Resource Reduction Strategies	• Develop methods and culture for reduced resource consumption • Integrate climate considerations into clinical decision support for sustainable practices
	Climate Informatics Integration	• Integrate climate change into healthcare informatics frameworks • Develop climate-specific clinical coding for evaluation and measurement • Establish core climate health data elements for informatics
	Environmental Justice and Equity	• Address challenges of measuring climate impact on Indigenous populations • Use novel simulation methods to model health challenges (syndemicity)
	Geospatial Mapping and Risk Assessment	• Build risk prediction models with AI and simulation • Research environmental determinants of health • Establish data vocabulary for spatio-temporal information retrieval and analysis • Use GIS for heat island mapping and environmental risk analysis • Employ wearables for remote patient monitoring (body temp, sweat, etc.) • Leverage NASA/NOAA data for climate health risk indicators • Improve surveillance and risk stratification (examples: heat-related conditions in vulnerable populations) • Identify mental health impacts of climate change
Finance and ROI	Business Case for Climate Action	• Demonstrate how climate measures improve organizational bottom line • Research cost incentives for environmental improvement
Miscellaneous	Policy Development for Food Systems	• Investigate policies to shift food production away from fat- and sugar-rich options (eg, targeting fast food and manufacturers)

vector-borne disease, we must connect data sets about climate, weather, geography, ecology, entomology, virology and bacteriology, clinical care, and public health. Informatics, with its competence in developing data standards, structures, mappings, and analytical methods, is a key discipline in realizing these connections.

7) *Education and training on climate, health, and informatics*: The contribution of physicians (and, by inference, all health professionals) to adaptation and mitigation is based on a professional ethos emphasizing their responsibility for the wellbeing of individuals and populations, now and in the future.[50,56] As a result, many initiatives developing competencies and approaches to address the need for education about climate change in the context of human and planetary health have been developed.[43,44] Informatics is not only essential in the delivery of health education[57] but also as a topic in its own right.[58] Education about climate and health, and their intersection with informatics, should therefore be integrated in *all* health science curricula.

While the mini-summit brought together participants from a wide variety of disciplines within the informatics field (such as members of AMIA as well as the International Medical Informatics Association and the International Academy of Health Sciences Informatics) as well as professional connections of the authors themselves, the expert recruitment process for the event was not conducted systematically, possibly leading to selection bias. Defining priority practice and

research areas at the intersection of climate, health, and informatics comprehensively and systematically will require a rigorous, long-term, and continually evolving process.

Conclusion

The AMIA 2023 *Mini-Summit on Climate, Health, and Informatics* was our inaugural initiative to mobilize informaticians to confront the urgent challenges of climate change, laying the groundwork for sustained action and collaboration. The mini-summit discussions and the affinity diagramming exercise were valuable tools to engage and harness the collective expertise within our AMIA membership, and begin to establish priorities for informatics-based research and practical actions for the healthcare profession. The outcomes of the mini-summit will help shape the evolving charter of the AMIA *Climate, Health, and Informatics Working Group* in creating a strategic roadmap for climate informatics research. This group will serve as a focal point for exchanging knowledge, driving innovative solutions, guiding the development of evidence-based practices, and fostering engagement and mentorship for future informaticians engaged in climate change. Simultaneously, efforts are underway to establish an informatics emphasis area for climate change research, and make the topic an integral part of AMIA conferences and symposia going forward. These collective endeavors are the first of many required to achieve a broader vision to leverage AMIA and its community for heightened awareness and education, partner and community engagement, and public policy in the face of a rapidly changing climate. The AMIA 2023 Mini-Summit laid the groundwork for sustained action in climate health informatics, but the journey is just beginning. As we continue to build on these initial steps, the informatics community must remain at the forefront, driving innovation, research, and inter-disciplinary collaboration to address one of the most critical challenges of our time.

Acknowledgments

We gratefully acknowledge the support provided by Regenstrief Institute, the International Academy of Health Sciences Informatics, the International Medical Informatics Association, and the American Medical Informatics Association. Dr Schleyer's effort was funded, in part, by Indiana University Health and the Indiana Clinical and Translational Sciences Institute, funded in part by grant ULI TR002529 from the National Institutes of Health, National Center for Advancing Translational Sciences, Clinical and Translational Science Award. The authors also extend a special note of gratitude to the mini-summit panelists Dr Melissa Gonzales (Chair of Environmental Health Sciences Department, Tulane University) and Dr Sundee Winder (Executive Director of Public Health Preparedness, Louisiana Department of Health, Office of Public Health), as well as the members of the Working Group who contributed to this manuscript (specifically, Harry Hochheiser, Felix Holl, Michael Kamerick, Vipina Keloth, Carolyn Petersen, Tony Solomonides, and Anthony Sunyaya). We also want to thank the participants for their invaluable knowledge, expertise, and active participation in the affinity diagramming exercise. Their dedication has been instrumental in advancing the role of informatics in addressing climate change and is greatly appreciated. We also thank Lynn Whittaker for her assistance with editing this manuscript.

Author contributions

Titus Schleyer contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the conception or design of the work as well as the acquisition, analysis, or interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Manijeh Berenji contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the conception or design of the work as well as the acquisition, analysis, or interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Monica Deck contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition of data for the work; drafting the work; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Hana Chung contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Joshua Choi contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Theresa A. Cullen contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Timothy Burdick contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Amanda Zaleski contributed to the paper according to the ICMJE guidelines for authorship including:

substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Kelly Jean Thomas Craig contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Oluseyi Fayanju contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Muhammad Muinul Islam contributed to the paper according to the ICMJE guidelines for authorship including: substantial contributions to the acquisition, analysis, and interpretation of data for the work; drafting the work or reviewing it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of interest

A.Z. and K.J.T.C are employed by CVS Health® Corporation and receive equity and own stock.

References

1. Romanello M, Napoli CD, Green C, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *Lancet*. 2023;402:2346-2394. https://doi.org/10.1016/S0140-6736(23)01859-7
2. Schramm PJ, Hayden MH, Beard CB, et al. *Human Health*. Washington, DC: U.S. Global Change Research Program; 2023.
3. The Health Care Costs of Extreme Heat. Center for American Progress. 2023. Accessed August 16, 2024. https://www.americanprogress.org/article/the-health-care-costs-of-extreme-heat/
4. Ebi KL, Capon A, Berry P, et al. Hot weather and heat extremes: health risks. *Lancet*. 2021;398:698-708. https://doi.org/10.1016/S0140-6736(21)01208-3
5. Tran HM, Tsai F-J, Lee Y-L, et al. The impact of air pollution on respiratory diseases in an era of climate change: a review of the current evidence. *Sci Total Environ*. 2023;898:166340. https://doi.org/10.1016/j.scitotenv.2023.166340
6. Blaustein JR, Quisel MJ, Hamburg NM, et al. Environmental impacts on cardiovascular health and biology: an overview. *Circ Res*. 2024;134:1048-1060. https://doi.org/10.1161/CIRCRESAHA.123.323613
7. People Who Are Vulnerable to Climate Change. National Institute of Environmental Health Sciences. Accessed August 17, 2024. https://www.niehs.nih.gov/research/programs/climatechange/health_impacts/vulnerable_people
8. US EPA O. Climate Change and Human Health: Who's Most at Risk? 2022. Accessed August 17, 2024. https://www.epa.gov/climateimpacts/climate-change-and-human-health-whos-most-risk
9. Rocklöv J, Dubrow R. Climate change: an enduring challenge for vector-borne disease prevention and control. *Nat Immunol*. 2020;21:479-483. https://doi.org/10.1038/s41590-020-0648-y
10. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. *Ann N Y Acad Sci*. 2019;1436:157-173. https://doi.org/10.1111/nyas.13950
11. Thomson MC, Stanberry LR. Climate change and vectorborne diseases. *N Engl J Med*. 2022;387:1969-1978. https://doi.org/10.1056/NEJMra2200092
12. Mojahed N, Mohammadkhani MA, Mohamadkhani A. Climate crises and developing vector-borne diseases: a narrative review. *Iran J Public Health*. 2022;51:2664-2673. https://doi.org/10.18502/ijph.v51i12.11457
13. Gray K. Climate change, human health, and health informatics: a new view of connected and sustainable digital health. *Front Digit Health*. 2022;4:869721. https://doi.org/10.3389/fdgth.2022.869721
14. About AMIA | AMIA—American Medical Informatics Association. Accessed August 17, 2024. https://amia.org/about-amia
15. What is an Affinity Diagram? K-J Method | ASQ.Accessed August 17, 2024. https://asq.org/quality-resources/affinity
16. What is the Difference Between Adaptation and Mitigation? | European Environment Agency's Home Page. Accessed August 16, 2024. https://www.eea.europa.eu/en/about/contact-us/faqs/what-is-the-difference-between-adaptation-and-mitigation
17. Medical Subject Headings—Home Page. Accessed August 16, 2024. https://www.nlm.nih.gov/mesh/meshhome.html
18. Doo FX, Vosshenrich J, Cook TS, et al. Environmental sustainability and AI in radiology: a double-edged sword. *Radiology*. 2024;310:e232030. https://doi.org/10.1148/radiol.232030
19. Brook JR, Setton EM, Seed E, et al.; CANUE—The Canadian Urban Environmental Health Research Consortium. The Canadian Urban Environmental Health Research Consortium—a protocol for building a national environmental exposure data platform for integrated analyses of urban form and health. *BMC Public Health*. 2018;18:114. https://doi.org/10.1186/s12889-017-5001-5
20. Fleming LE, Haines A, Golding B, et al. Data mashups: potential contribution to decision support on climate change and health. *Int J Environ Res Public Health*. 2014;11:1725-1746. https://doi.org/10.3390/ijerph110201725
21. Tamburis O, Benis A; Section Editors for the IMIA Yearbook Special Topic Section on Informatics for One Health. Leveraging data and technology to enhance interdisciplinary collaboration and health outcomes. *Yearb Med Inform*. 2023;32:84-88. https://doi.org/10.1055/s-0043-1768753
22. Lokmic-Tomkins Z, Block LJ, Davies S, et al. Evaluating the representation of disaster hazards in SNOMED CT: gaps and opportunities. *J Am Med Inform Assoc*. 2023;30:1762-1772. https://doi.org/10.1093/jamia/ocad153
23. Maynard NG, Conway GA. A view from above: use of satellite imagery to enhance our understanding of potential impacts of climate change on human health in the Arctic. *Alaska Med*. 2007;49:78-85.
24. Bakken S. Climate change, security, privacy, and data sharing: important areas for advocacy and informatics solutions. *J Am Med Inform Assoc*. 2021;28:2072-2073. https://doi.org/10.1093/jamia/ocab188

25. Ceccato P, Ramirez B, Manyangadze T, et al. Data and tools to integrate climate and environmental information into public health. *Infect Dis Poverty*. 2018;7:126. https://doi.org/10.1186/s40249-018-0501-9
26. Corral J D, Blumenthal MB, Mantilla G, et al. Climate information for public health: the role of the IRI climate data library in an integrated knowledge system. *Geospat Health*. 2012;6:S15-S24. https://doi.org/10.4081/gh.2012.118
27. Schmitz-Grosz K, Sommer-Meyer C, Berninger P, et al. A telemedicine center reduces the comprehensive carbon footprint in primary care: a monocenter, retrospective study. *J Prim Care Community Health*. 2023;14:21501319231215020. https://doi.org/10.1177/21501319231215020
28. Adshead F, Salman RA-S, Aumonier S, et al. A strategy to reduce the carbon footprint of clinical trials. *Lancet*. 2021;398:281-282. https://doi.org/10.1016/S0140-6736(21)01384-2
29. Smith CL, Zurynski Y, Braithwaite J. We can't mitigate what we don't monitor: using informatics to measure and improve healthcare systems' climate impact and environmental footprint. *J Am Med Inform Assoc*. 2022;29:2168-2173. https://doi.org/10.1093/jamia/ocac113
30. Sittig DF, Sherman JD, Eckelman MJ, et al. i-CLIMATE: a "clinical climate informatics" action framework to reduce environmental pollution from healthcare. *J Am Med Inform Assoc*. 2022;29:2153-2160. https://doi.org/10.1093/jamia/ocac137
31. Sijm-Eeken ME, Arkenaar W, Jaspers MW, et al. Medical informatics and climate change: a framework for modeling green healthcare solutions. *J Am Med Inform Assoc*. 2022;29:2083-2088. https://doi.org/10.1093/jamia/ocac182
32. Cummins MR, Shishupal S, Wong B, et al. Travel distance between participants in US telemedicine sessions with estimates of emissions savings: observational study. *J Med Internet Res*. 2024;26:e53437. https://doi.org/10.2196/53437
33. Sepetis A, Rizos F, Pierrakos G, et al. A sustainable model for healthcare systems: the innovative approach of ESG and digital transformation. *Healthcare (Basel)*. 2024;12:156. https://doi.org/10.3390/healthcare12020156
34. Lokmic-Tomkins Z, Davies S, Block LJ, et al. Assessing the carbon footprint of digital health interventions: a scoping review. *J Am Med Inform Assoc*. 2022;29:2128-2139. https://doi.org/10.1093/jamia/ocac196
35. Rahimi-Ardabili H, Magrabi F, Coiera E. Digital health for climate change mitigation and response: a scoping review. *J Am Med Inform Assoc*. 2022;29:2140-2152. https://doi.org/10.1093/jamia/ocac134
36. Di Giacomo P, Håkansson P. A method to measure the reduction of CO2 emissions in E-health applications. *Stud Health Technol Inform*. 2011;169:970-974.
37. Phuong J, Riches NO, Calzoni L, et al. Toward informatics-enabled preparedness for natural hazards to minimize health impacts of climate change. *J Am Med Inform Assoc*. 2022;29:2161-2167. https://doi.org/10.1093/jamia/ocac162
38. Fard P, Chung MKJ, Estiri H, et al. Spatio-temporal interpolation and delineation of extreme heat events in California between 2017 and 2021. *Environ Res*. 2023;237:116984. https://doi.org/10.1016/j.envres.2023.116984
39. Prudent N, Houghton A, Luber G. Assessing climate change and health vulnerability at the local level: Travis County, Texas. *Disasters*. 2016;40:740-752. https://doi.org/10.1111/disa.12177
40. Krstic N, Yuchi W, Ho HC, et al. The Heat Exposure Integrated Deprivation Index (HEIDI): a data-driven approach to quantifying neighborhood risk during extreme hot weather. *Environ Int*. 2017;109:42-52. https://doi.org/10.1016/j.envint.2017.09.011
41. Lee WL, Gu X, Armas F, et al. Monitoring human arboviral diseases through wastewater surveillance: challenges, progress and future opportunities. *Water Res*. 2022;223:118904. https://doi.org/10.1016/j.watres.2022.118904
42. Bernier E, Gosselin P, Badard T, et al. Easier surveillance of climate-related health vulnerabilities through a web-based spatial OLAP application. *Int J Health Geogr*. 2009;8:18. https://doi.org/10.1186/1476-072X-8-18
43. Kline MC, Malits JR, Baker N, et al. Climate change, environment, and health: the implementation and initial evaluation of a longitudinal, integrated curricular theme and novel competency framework at Harvard Medical School. *PLoS Clim*. 2024;3:e0000412. https://doi.org/10.1371/journal.pclm.0000412
44. Wabnitz K, Schwienhorst-Stich E-M, Asbeck F, et al. National Planetary Health learning objectives for Germany: a steppingstone for medical education to promote transformative change. *Front Public Health*. 2022;10:1093720. https://doi.org/10.3389/fpubh.2022.1093720
45. Abrham Y, Zeng S, Tenney R, et al. Effect of a single one-hour teaching session about environmental pollutants and climate change on the understanding and behavioral choices of adolescents: The BREATHE pilot randomized controlled trial. *PLoS One*. 2023;18:e0291199. https://doi.org/10.1371/journal.pone.0291199
46. Abdolkhani R, Choo D, Gilbert C, et al. Advancing women's participation in climate action through digital health literacy: gaps and opportunities. *J Am Med Inform Assoc*. 2022;29:2174-2177. https://doi.org/10.1093/jamia/ocac167
47. Sarabu C, Deonarine A, Leitner S, et al. Climate change and health informatics: pilot survey of perspectives across the field. *J Am Med Inform Assoc*. 2022;29:2117-2123. https://doi.org/10.1093/jamia/ocac199
48. Uliniansyah MT, Budi I, Nurfadhilah E, et al. Twitter dataset on public sentiments towards biodiversity policy in Indonesia. *Data Brief*. 2024;52:109890. https://doi.org/10.1016/j.dib.2023.109890
49. Heneghan J, John DC, Bartsch SM, et al. A systems map of the challenges of climate communication. *J Health Commun*. 2024;29:77-88. https://doi.org/10.1080/10810730.2024.2361842
50. Coiera E, Magrabi F. What did you do to avoid the climate disaster? A call to arms for health informatics. *J Am Med Inform Assoc*. 2022;29:1997-1999. https://doi.org/10.1093/jamia/ocac185
51. Atwoli L, Baqui AH, Benfield T, et al. Call for emergency action to limit global temperature increases, restore biodiversity, and protect health. *J Am Med Inform Assoc*. 2021;28:2069-2071. https://doi.org/10.1093/jamia/ocab178
52. Porter WT, Barrand ZA, Wachara J, et al. Predicting the current and future distribution of the western black-legged tick, Ixodes pacificus, across the Western US using citizen science collections. *PLoS One*. 2021;16:e0244754. https://doi.org/10.1371/journal.pone.0244754
53. Ottaviano M, Beltrán-Jaunsarás ME, Teriús-Padrón JG, et al. Empowering citizens through perceptual sensing of urban environmental and health data following a participative citizen science approach. *Sensors (Basel)*. 2019;19:2940. https://doi.org/10.3390/s19132940
54. Jaffe C, Nguyen V, Kubick WR, et al. Standards in biomedical informatics. In: Shortliffe EH, Cimino JJ, eds. *Biomedical Informatics: Computer Applications in Health Care and Biomedicine*. Cham: Springer International Publishing; 2021:205-240.
55. Wilkinson MD, Dumontier M, Aalbersberg IJJ, et al. The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data*. 2016;3:160018. https://doi.org/10.1038/sdata.2016.18
56. Parsa-Parsi RW. The international code of medical ethics of the World Medical Association. *JAMA*. 2022;328:2018-2021. https://doi.org/10.1001/jama.2022.19697
57. Dev P, Schleyer T. *Digital Technology in Health Science Education. Biomedical Informatics: Computer Applications in Health Care and Biomedicine*. Cham: Springer International Publishing; 2021.
58. Lee KH, Kim M-G, Lee J-H, et al. Empowering healthcare through comprehensive informatics education: the status and future of biomedical and health informatics education. *Healthc Inform Res*. 2024;30:113-126. https://doi.org/10.4258/hir.2024.30.2.113

Journal of the American Medical Informatics Association, 2025, 00, 1–9
https://doi.org/10.1093/jamia/ocae292
Perspective