

Climate and health: How can informatics help?

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Climate change is an alarming global threat to individual and public health. The acceleration of climate-related exposures such as extreme weather events, rising sea levels, and temperature fluctuations have direct and indirect implications for human health¹. Increased frequency of health-threatening hot days and poor air quality are associated with a greater risk of heat-related illnesses and respiratory complications, which disproportionately impacts vulnerable populations such as children, older adults, individuals with chronic conditions, and people without homes^{1,2}. Increased occurrence and severity of extreme weather events, including hurricanes, floods, wildfires, and heatwaves, cause direct physical and/or environmental harm (i.e., injury, displacement, environmental degradation, and saltwater intrusion)¹. Additional long-term sequelae of climate change are numerous, including the spread of diseases such as dengue and malaria to areas that were previously non-endemic, alongside the emergence of other pathogenic conditions^{3,4}. The most recent report of the Lancet Countdown on health and climate change presents sobering projections for the health and survival of people worldwide unless “profound and immediate systemic changes” are made¹. Most notably, the report forecasts a disturbing trajectory in key indicators for global progress including: a 370% increase in heat-related deaths; an additional 525M individuals facing moderate-to-severe food insecurity; and a ~36% increase in the transmission of dengue disease (under a 2°C surface temperature scenario) by mid-century¹.

Amidst these escalating health concerns emerges a critical role for the field of biomedical informatics, the application of data, information, and knowledge as related to human health. Quantifying the continued impact of climate change is essential to developing transformative and effective strategies to measure, mitigate, and adapt to a rapidly changing climate⁵. Indeed, the 2023 Lancet Countdown identified 11 priorities for accelerated action to limit climate change and its health impacts. Notably, *all* recommendations anchor on climate-informed data surveillance with four priorities specifically calling for strengthened global capacity to support climate change research and knowledge generation¹. Addressing the climate crisis requires a dynamic framework that integrates diverse data sources, including, but not limited to meteorologic, geospatial, clinical, public health, and socioeconomic data. Combined with advanced analytics, the amalgamation of these data can foster early awareness; establish real-time alert systems; inform the design and development of predictive models; and ultimately translate to scalable innovations that reduce or eliminate the anthropogenic impact of GHG emissions. However, given its urgency and the public health implications, an undertaking of this magnitude necessitates strategic direction and concerted collaboration.

Biomedical informatics, an academic field focused on data, computer sciences, knowledge, and wisdom as related to human health, is thus essential to support our attempts to understand, mitigate, and adapt to climate change.

To that end, the American Medical Informatics Association (AMIA) hosted a Mini-Summit entitled *Climate and health: How can informatics help?* (“Mini-Summit”) on November 11, 2023. Briefly, AMIA is the leading professional association for >5,500 transdisciplinary subject matter experts committed to the practice of informatics as it relates to clinical care, research, education, and policy⁶. The primary aims of the Mini-Summit were to a) initiate dialogue on the impact of climate change on public health and b) facilitate an open forum to identify potential opportunities, solutions, and collaborations at the intersection of climate change and population health.

All attendees were registered to attend the AMIA 2023 Annual Symposium (New Orleans, LA, USA) and invited to participate in the Mini-Summit. Leveraging an Affinity Diagramming methodological approach defined *a priori* (Indiana University IRB Protocol #21183), Mini-Summit staff posed two questions to ~50 attendees (40 in-person; 10 virtual)⁷:

1. **Action/implementation:** What evidence-based practices can individuals, groups and organizations in healthcare apply/implement *now* to help (1) mitigate or (2) adapt to climate change (Please focus on things people can do at work, so no home-recycling, etc.)?*
2. **Research:** What research should the informatics community conduct to help healthcare (1) mitigate or (2) adapt to climate change? This research will enable/produce evidence-based practices for action/implementation.

The rationale for posing two separate, but distinct questions was to identify actions that healthcare can take *now* to mitigate or adapt to climate change while acknowledging that additional approaches and solutions will have to be developed. Dedicated informatics-informed research efforts will be pivotal to devise novel strategies for the mitigation of or adaptation to climate change. While we considered the two areas as mainly separate, a certain degree of overlap in the responses was expected and acknowledged. All responses were recorded by Mini-Summit staff (HC, JC, MD, TS) and synthesized below (MB, HC, JC, MK, TS) to identify current- and future-state priorities for implementation and research.

Attendees’ ideas were recorded in affinity diagrams, which are visual tools that help organize information from a brainstorming session. Affinity diagramming is an inductive exercise in which individual, specific insights are recorded on Post-it™ notes and gathered into groups. Each group of notes has some similarity in intent, problem, or issue. Groups are then labeled with a descriptive, summary note. Grouping continues until each cluster of notes is summarized and all themes from the original insights are represented. At the Mini-Summit, attendees were asked to consider the aforementioned questions and record their ideas.

The rationale for asking the two questions separately was that there are evidence-based practices *today* that are known to reduce GHG and conserve natural resources. It is important to examine when and how healthcare organizations could apply them. At the same time, research is needed to find out what else we can do to understand how to mitigate or adapt to climate change. While we considered the two areas as mainly separate, we also expected a certain degree of overlap in the responses.

Several themes emerged from the Action and Implementation activity summarized in Table 1. Building a climate-sensitive healthcare economy will require stakeholders to develop a cohesive strategy. This strategy should be multi-pronged, incorporating education, workforce

*“Mitigation” means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gasses. “Adaptation” is the process of adjusting to the current and future effects of climate change (Adapted from: European Environment Agency)

development, policy and regulatory frameworks, operational redesign, standardized metrics for evaluation and analysis, public-private partnerships, community resilience, emergency preparedness, financial stewardship, and clinical decision support. With respect to education, integrating climate literacy into all aspects of healthcare delivery will require a fundamental understanding of the individual and collective carbon footprint, and exploring ways in which humanity can further decarbonize the atmosphere in an equitable manner. Workforce development would involve educating dedicated climate health experts with cross-disciplinary capabilities. Creative policymaking will incentivize climate-friendly practices in the healthcare sector and beyond, such as using resources wisely and incorporating sustainability-focused practices. Transforming clinical operations will require reducing travel emissions from both clinicians as well as 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 operations. When it comes to measurement and evaluation procedures, it will be vital to establish real-time monitoring of climate impacts and resource utilization in the form of easily navigable dashboards as well as predictive modeling of future impacts. Multi-sectoral partnerships across governmental agencies, research institutions, community organizations, and business entities 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 (which includes IT resilience measures during natural disasters; minimum health record requirements in crisis response scenarios; and effective management of mass human displacement that could arise in a climate event) are essential so that clinical decision support and other informatics tools can guide healthcare providers accordingly.

In the Research exercise, participants focused on the following areas of investigation: (i) emergency preparedness; (ii) climate-centric healthcare delivery models; (iii) carbon footprint and associated costs; (iv) sustainability; (v) data analytics; (vi) finance and return on investment. Two key areas for emergency preparedness research included IT resilience capacity to include the evaluation of the current state of backup power solutions, data protection strategies, and alternative communication streams, and minimum necessary health and social determinants data collection and formatting to ensure that information is shared between first responders, clinicians, and other stakeholders cohesively. To optimize remote patient monitoring and other virtual medicine platforms, more research would need to be conducted exploring the level of electronic support needed; triaging those who need in-person assessment from those that do not, and facilitating interoperability in communication streams. When it comes to carbon-related research, it will be critical to quantify the carbon benefits of a telemedicine platform as well as connect with other like-minded individuals in the field so best practices can be shared. From a sustainability and data analytics perspective, integrating the climate health informatics framework into the healthcare informatics framework; identifying and enhancing clinical coding standards as well as developing new clinical coding standards; and forming a core set of data elements were seen as priorities. The application of biomedical informatics is imperative to measure, mitigate, and adapt to growing challenges owing to the impact of climate change on population health.

The AMIA 2023 Mini-Summit on Climate, Health, and Informatics represents our inaugural initiative to mobilize informaticians to confront the urgent challenge of climate change, laying the groundwork for sustained action and collaboration in this critical domain. The Mini-Summit's affinity diagramming exercise was a valuable tool to engage and harness the collective expertise within our membership and inform priorities for informatics-based research. Immediate next steps involve validating and aligning the results of the Mini-Summit affinity diagramming

exercise with the existing literature. These outcomes will directly shape the charter for a structured AMIA Working Group tasked with creating a strategic roadmap for prioritized climate change research. This community will serve as a network to exchange knowledge; drive innovative solutions; inform evidence-based practices; and foster engagement and mentorship for future informaticians engaged in climate change. Simultaneously, efforts are underway to establish a topical informatics emphasis area for climate change research and issue a call for submissions for forthcoming AMIA conferences, symposia, and summits. These collective endeavors represent the first of many activities required to achieve a broader vision to leverage AMIA's platform for heightened awareness and education, community engagement, and impactful influence on public policy in the face of a rapidly changing climate.

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Conflicts of Interest: AZ and KJTC are employed by CVS Health® Corporation and receive equity and own stock.

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Additional Resources:

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Table 1: Action and Implementation

Area	Action	Implementation
Literacy and Education	Increase awareness of climate change impacts	<ul style="list-style-type: none"> • Locally: Host educational workshops & community events • Regionally: Collaborate with public health agencies & NGOs • Nationally: Advocate for climate education initiatives • Internationally: Support global health partnerships
	Track carbon footprint	<ul style="list-style-type: none"> • Individual: Assess personal & professional carbon footprint • Healthcare organization: Conduct carbon footprint audits
	Foster climate-friendly choices	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Upskill existing healthcare professionals in climate science & resilience • Educate future healthcare workers on climate-sensitive care • Create career pathways for climate-focused healthcare roles
Regulations and Policy	Incentivize climate-friendly practices	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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 & public health data sharing
Healthcare Operations	Reduce patient & clinician travel	<ul style="list-style-type: none"> • Promote public transit & bicycle incentives for staff & patients • Expand telemedicine & virtual care options • Optimize clinical workflows to minimize travel needs
	Source renewable energy	<ul style="list-style-type: none"> • Invest in on-site renewable energy generation (eg, solar panels) • Purchase & advocate for clean energy from local providers • Track & report progress towards renewable energy targets
	Prioritize resource efficiency	<ul style="list-style-type: none"> • Reduce dependence on disposables (eg, switch to reusable supplies) • Minimize paper & 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	<ul style="list-style-type: none"> • Implement real-time monitoring systems for resource consumption & emissions • Design feedback loops to continuously improve sustainability performance • Integrate climate change metrics into existing healthcare performance models
Partnerships	Foster cross-sector collaboration	<ul style="list-style-type: none"> • Build partnerships with environmental organizations, government agencies, & public health departments • Engage with communities most affected by climate change • Collaborate with national EHR vendors & technology providers
Community Adaptation and Resources	Assess community vulnerability	<ul style="list-style-type: none"> • Identify populations at increased risk from climate impacts • Develop resource allocation plans based on social vulnerability indices
	Predict resource needs	<ul style="list-style-type: none"> • Utilize data analytics to predict climate events & associated resource requirements • Prepare essential resources (eg, cooling centers, medications) for vulnerable populations
Analytics	Optimize clinical & administrative efficiency	<ul style="list-style-type: none"> • Implement data dashboards to track energy use, resource consumption, & waste production Leverage analytics to identify opportunities for sustainability improvements
Emergency Preparedness	Enhance healthcare resilience	<ul style="list-style-type: none"> • Conduct vulnerability assessments for healthcare facilities & IT systems • Develop disaster preparedness plans for extreme weather events • Establish protocols for minimum health record access during crisis response • Prepare for mass displacement & refugee situations
Finance	Make climate action financially viable	<ul style="list-style-type: none"> • Demonstrate the cost-savings potential of sustainable healthcare practices • Secure funding & grants for climate-related initiatives • Develop innovative financing models for clean energy investments
Clinical Decision Support	Encourage climate-friendly choices	<ul style="list-style-type: none"> • 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

Table 2: Research

Area	Research Focus	Examples
Emergency Preparedness	IT Resilience	<ul style="list-style-type: none"> • Strengthening IT infrastructure against disasters (floods, outages) • Defining minimum health and social record for crisis response
	Telehealth Optimization	<ul style="list-style-type: none"> • Improving virtual consultations to reduce traffic • Optimizing telemedicine efficiency and effectiveness • Determining optimal levels of electronic support (text, voice, video)
	Remote Examination Solutions	<ul style="list-style-type: none"> • Researching methods for remote physical exams or assessments • Enhancing patient information sharing (images, documents, DICOM files) • Exploring the use of templates and structured communication formats
	Clinician Workload Management	<ul style="list-style-type: none"> • Investigating clinician capacity for multi-patient management (help desk model) • Exploring incentives for green transportation options • Optimizing clinician and patient commuting
Cost and Carbon Footprint	Resource and Workflow Assessment	<ul style="list-style-type: none"> • Comparing carbon footprints of healthcare resources, materials, and workflows • Quantifying telehealth carbon benefits across different regions • Designing climate-conscious health interventions • Categorizing and labeling energy costs throughout asset lifecycles
	Consumer Preferences and Expectations	<ul style="list-style-type: none"> • Researching consumer expectations around virtual care's carbon footprint • Optimizing hospital size for minimum climate impact
Sustainability	Resource Reduction Strategies	<ul style="list-style-type: none"> • Developing methods and culture for reduced resource consumption • Integrating climate considerations into clinical decision support for sustainable practices
	Climate Informatics Integration	<ul style="list-style-type: none"> • Integrating climate change into healthcare informatics frameworks • Developing climate-specific clinical coding for evaluation and measurement • Establishing core climate health data elements for informatics
	Environmental Justice and Equity	<ul style="list-style-type: none"> • Addressing challenges of measuring climate impact on indigenous populations • Utilizing novel simulation methods to model health challenges (syndemicity) • Building risk prediction models with AI and simulation • Researching environmental determinants of health

Geospatial Mapping
and Risk Assessment

- Establishing data vocabulary for spatio-temporal information retrieval and analysis
- Utilizing GIS for heat island mapping and environmental risk analysis
- Employing wearables for remote patient monitoring (body temp, sweat, etc)
- Leveraging NASA/NOAA data for climate health risk indicators
- Improving surveillance and risk stratification (examples: heat-related conditions in vulnerable populations)
- Identifying mental health impacts of climate change

**Finance and
ROI**

Business Case for
Climate Action

- Demonstrating how climate measures improve organizational bottom line
- Researching cost incentives for environmental improvement

Miscellaneous

Policy Development
for Food Systems

- Investigating policies to shift food production away from fat- and sugar-rich options (eg, targeting fast food and manufacturers)