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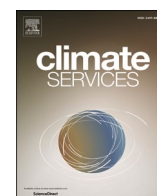
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An AI visual chatbot system for climate heat risk communication and decision-making in at-risk agricultural communities

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HIGHLIGHTS

- AI chatbot “Sol” promptly delivers heat risk information to farmworkers and stakeholders.
- Real-time heat stress visualization on smartphones, tablets and computers using the NOAA forecast data.
- “Sol” uses Llama 3.2-Vision and prompt engineering to give context-specific guidance from Wet Bulb Globe Temperature data.
- Provides accessible heat safety advice to vulnerable populations in English and Spanish in Imperial Valley, California.

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ABSTRACT

Information on heat-related health risks that is based on meteorological data and forecasts is important for outdoor workers, farm managers, and many other stakeholders, but visualization and interpretation of climate data in a user-friendly way remains a challenge. This proof-of-concept research developed Sol, an artificial intelligence (AI) chatbot to conveniently interpret and communicate heat stress risks through smartphones and other devices. Sol is integrated into iHeatApp, a wet bulb globe temperature (WBGT) forecast visualization tool, to turn complex climate data into practical guidance with bilingual output in English and Spanish. The chatbot leverages an open source large language model (LLM) constrained by prompt engineering designs to reduce hallucinations and encourage domain-specific responses. The chatbot input may be either text or screenshot of the app's interface. Guided by our tutorial materials, we gathered farmworker feedback on the chatbot's ability to translate complex weather metrics into risk mitigation actions using focus groups of farmworkers from the Imperial Valley, California. When WBGT forecast values reach the “danger” category, the chatbot recommends wearing light, breathable clothing and increasing water breaks to prevent heat stress. Our app can help both farmworkers and their managers adapt work scheduling decisions to avoid the risks of peak heat and other health hazards and to mitigate labor productivity loss.

Practical implications

Climate heat stress is a major occupational hazard for farmworkers, threatening health, safety, and productivity in outdoor agricultural environments. Farmworkers in regions such as California's Imperial Valley frequently work long hours under direct sun, are exposed to high temperatures, and face fatal heat-related outcomes. Chronic exposure to such conditions has been linked to heat exhaustion, heatstroke, and kidney disease resulting from recurrent dehydration and thermal strain. These risks are intensified by structural vulnerabilities such as limited

access to healthcare, language barriers, and insufficient rest and hydration breaks. The frequent and prolonged heat waves in California's Imperial Valley highlight that the need for accessible real-time communication of heat risk information has become a public health priority.

Recent advances in conversational artificial intelligence (CAI) have created new opportunities to make scientific information more accessible through natural language interaction. Chatbots powered by CAI can be useful climate service tools for communicating environmental and health risks with their abilities to interpret data, respond to

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questions, and provide guidance in multiple languages. This study applies CAI to translate the Wet Bulb Globe Temperature (WBGT) forecasts into clear and practical messages that help farmworkers understand and respond to extreme heat. WBGT is widely recognized as the standard metric for assessing heat stress and determining safe environmental working conditions, while temperature alone cannot. WBGT integrates the effects of temperature, humidity, solar radiation, and wind to provide a more complete measure of environmental heat load on the human body. However, while WBGT forecasts are increasingly available from public data sources such as the National Weather Service's National Blend of Models (NBM), the data are typically presented in scientific formats that are difficult for non-specialists to access and interpret. This communication gap limits the ability of workers and supervisors to make timely decisions about hydration, rest breaks, and clothing choices that could prevent heat-related illness.

To help close this gap, we developed a bilingual AI-powered conversational agent named Sol as a climate service tool. Sol interprets WBGT forecasts into accessible heat-safety guidance. Sol was integrated into the iHeatApp platform, which visualizes WBGT forecasts for the Imperial Valley using open NOAA data. The chatbot allows users to type questions or upload screenshots of the forecast map to transform the scientific information displayed in the app into personalized recommendations. The friendly Sol enables users, particularly the farmworkers, to engage directly with complex forecast data through simple conversations.

Sol was developed and tested through participatory sessions with farmworkers in collaboration with *Líderes Campesinas*, a community organization that supports agricultural workers in California's Imperial Valley. During these sessions, participants interacted directly with the bilingual chatbot using their own smartphones to test how it interpreted WBGT forecasts and provided safety recommendations. Feedback from farmworkers guided updates to the chatbot's functionality and phrasing to make responses more clear and easy to understand. Farmworkers affirmed that Sol's guidance was useful for staying safe during periods of high heat because it communicated in Spanish and offered practical and situation-specific advice.

During testing, Sol demonstrated how complex WBGT data can be transformed into brief and useful guidance. In one case, a farmworker preparing for an afternoon shift near Brawley used iHeatApp to view the 3:00 p.m. forecast, captured a screenshot of the heatmap, and sent it to Sol. Within seconds, the chatbot analyzed the WBGT, identified the heat-risk category, and recommended more frequent rest breaks, increased hydration, and avoiding working during peak hours. In another instance, a worker asked, “¿Qué ropa debería usar hoy?” (“What clothes should I wear today?”). Sol interpreted a WBGT of 74 °F (Caution) and replied in Spanish with practical attire advice of wearing light-colored and breathable fabrics and a wide-brimmed hat while warning against tight garments. Participants found these personalized, bilingual messages both relatable and useful. These examples illustrate how the chatbot converts forecasts into culturally relevant, behavior-focused heat-safety guidance.

Sol's reliability depends on structured prompt engineering that constrains responses to verified WBGT categories and established heat-safety recommendations. Guardrails prevent speculation and ensure concise, factual outputs aligned with recognized guidance. This approach maintains credibility while preserving the natural conversational tone that encourages user engagement. Because Sol is built on open data and infrastructure, it can be adapted to other regions, languages, or hazards such as air quality or wildfire smoke alerts.

For policymakers and practitioners, Sol provides a good example of how conversational AI can operationalize climate information for vulnerable communities. The iterative process used to build Sol matters as much as the technology developed. In-person feedback sessions let farmworkers shape the chatbot's language and recommendations directly. Other climate service teams working with vulnerable populations could use the same approach, regardless of the specific hazard

or platform. Its integration with real-time forecast data and bilingual communication makes it a scalable addition to state or county heat-illness prevention programs. Employers could embed similar chatbots into workplace safety training, enabling crews to access personalized guidance in their preferred language. Agencies could integrate them into early-warning systems to strengthen outreach and compliance with heat-safety standards. The system's low cost and open architecture make it suitable for replication across agricultural, construction, and other outdoor labor sectors.

Beyond its technical function, Sol demonstrates how climate services can evolve from data products to interactive, user-centered tools that translate scientific information into protective guidance. The chatbot's participatory development and bilingual design illustrate how artificial intelligence can enhance occupational safety while promoting equity in access to climate information. Its deployment in the Imperial Valley shows that when forecast data are communicated through intuitive, culturally familiar technology, workers can make more informed decisions about hydration, rest, and protection from the sun.

Case context

Extreme heat exposure poses a critical occupational health risk for farmworkers, compromising both physiological and psychological well-being. The Wet Bulb Globe Temperature (WBGT) is widely recognized as the standard metric for assessing heat stress and determining safe environmental working conditions (Budd, 2008). Accurate WBGT information is particularly essential in agricultural settings, where workers are frequently exposed to direct solar radiation and high humidity levels that exacerbate heat stress (Ahn et al., 2022; Clark et al., 2024). Recent studies have linked chronic exposure to high WBGT conditions with heat-related illnesses, including heat exhaustion, heat-stroke, and chronic kidney disease resulting from recurrent dehydration and thermal strain (Glaser et al., 2016). These health risks are intensified by the lack of adequate rest and protective measures commonly experienced by farmworkers (El Khayat et al., 2022; Langer et al., 2021). Accessibility to accurate WBGT forecasts plays a critical role in protecting the health and safety of farmworkers exposed to extreme heat (Parajuli et al., 2025). Farmworkers also face barriers to accessing digital health information due to limited internet connectivity and digital literacy, as highlighted by the North Carolina Farmworker Health Program's emergency initiative to expand internet access during the COVID-19 pandemic (Cofie et al., 2022). California's environmental justice research shows that the health and economic costs of climate change fall hardest on low-income, immigrant communities of color, who contributed least to the emissions driving it (Shonkoff et al., 2011). Imperial Valley farmworkers, largely foreign-born, Latino, and living below the poverty line, are one such population. For this population, accessible heat-risk communication is both a public health need and climate equity concern.

This research investigates the application of CAI, specifically chatbots, to effectively communicate environmental health risks, focusing on heat stress to vulnerable populations. CAI are AI-powered systems utilizing natural language processing (NLP), natural language understanding (NLU), and machine learning (ML) to create human-like conversational interfaces. While the term “chatbot” often describes the user interface, CAI encompasses more complex interactions beyond simple question-answering (Antu et al., 2023). Research highlights the increasing sophistication of CAI, including multilingual capabilities (Ahuja et al., 2023), personalization (Kocaballi et al., 2019), and emotional intelligence (Vicci, 2024), although these features are not always fully realized in existing systems. We address the application of CAI to interpret WBGT forecasts and communicate actionable insights to farmworkers in Imperial Valley, CA.

Despite the growing interest in CAI, several research gaps exist. While CAI applications are explored across various fields (Adamopoulou and Moussiades, 2020; Kulkarni et al., 2019), research specifically

targeting environmental risk communication to low-literacy or migrant populations remains limited. Some progress has been made in related domains. For example, chatbots have been used to democratize access to climate services (Koldunov and Jung, 2024), to support farmers with agricultural decision-making (Momaya et al., 2021), and to explore the role of generative AI in improving agricultural injury and illness surveillance (Weichelt et al., 2024). However, many studies focus on general health communication rather than environmental hazards. There is a need for AI heat risk assessment using the improved WBGT forecasts (Clark et al., 2024), which allows farmworkers to have optimal rest-break recommendations in southern California's Imperial and Coachella Valleys (Parajuli et al., 2025). Long-term analyses further highlight the disproportionate burden of extreme WBGT conditions on Imperial Valley communities, with frequent exceedances of the Occupational Safety and Health Administration (OSHA) thresholds and intensifying warming trends (Thompson et al., 2025). Yet, little attention has been given to how these advances are communicated to vulnerable populations in formats that are accessible and actionable.

Several key tools and technologies underpin this research. Large Language Models (LLMs), such as Meta's Llama 3.2-Vision (Meta AI, 2024), are central to many CAI systems. These models, trained on massive datasets, enable human-quality text generation and complex conversations (Antu et al., 2023). Our study leverages Llama 3.2-Vision, selected for its multilingual capabilities and image processing abilities, enabling the integration of screenshot uploads for interactive responses. Other relevant technologies include various chatbot development frameworks and web application frameworks, along with mapping libraries for data visualization. Reliable environmental data is crucial; this study utilizes WBGT forecasts from the NOAA National Blend of Models (NBM) (Hamill et al., 2017, and NOAA, 2025).

This study directly implements and tests the chatbot with farmworkers in the Imperial Valley. While some papers mention multilingual capabilities, few explicitly address the cultural nuances and communication styles of specific populations. This study prioritizes bilingual (English/Spanish) support, crucial for the Imperial Valley's predominantly Spanish-speaking agricultural workforce. Finally, the ability to

process visual information (e.g., screenshots) is a relatively unexplored area in environmental risk communication using CAI. This study leverages Llama 3.2-Vision's image processing capabilities to enhance user interaction and interpretation of WBGT forecasts. A significant gap in the literature is the lack of research on using conversational AI to communicate heat-related risks (WBGT) to low-literacy or migrant populations.

This study aims to bridge the communication gap between complex but useful WBGT forecasts and farmworkers in the Imperial Valley. Farmworkers often know basic heat-safety practices, such as drinking water, resting in shade, and wearing protective clothing. However, these decisions are often based on perceived heat rather than forecasted WBGT risk (Ciborowski et al., 2026). This creates a need for tools that connect familiar protective actions to specific WBGT conditions at a selected location and time. The design rationale is based on several key considerations: accessibility, actionability, usability, accuracy and reliability, and cultural sensitivity. The bilingual chatbot and user-friendly web application improve access to critical heat risk information, overcoming language barriers and potentially low digital literacy. Most NLP research and tools are built for a small number of high-resource languages, and speakers of other languages are often left out (Joshi et al., 2020). We built bilingual support into Sol from the start as a design requirement rather than an addition later. The chatbot translates complex WBGT data into actionable insights, guiding farmworkers on protective measures. The intuitive interface (Fig. 1), including screenshot upload functionality, enhances user engagement and interaction. The use of the NBM for WBGT forecasts and prompt engineering techniques for the LLM aim to ensure accurate and reliable information. Bilingual support and culturally appropriate messaging are crucial for effective communication with the target population.

This study employs a mixed-methods approach. First, WBGT forecast data are obtained from the NOAA NBM and displayed within iHeatApp. Second, a bilingual chatbot is developed using the LLaMA 3.2-Vision LLM, integrated into a React-based web application with a deck.gl map interface. Prompt engineering and guardrails are implemented to improve model performance and reduce hallucinations. Third, a testing

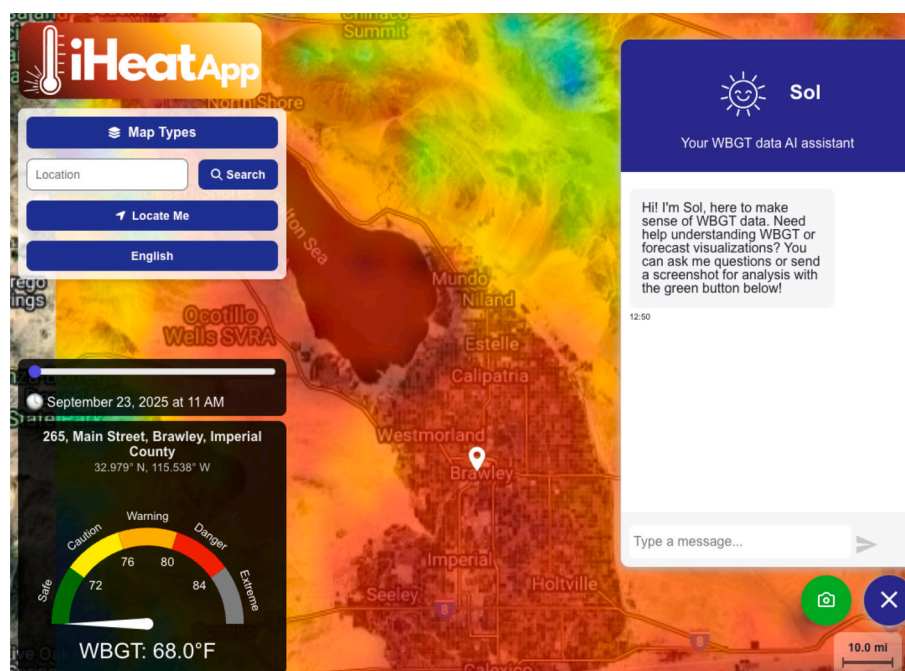


Fig. 1. The interface of iHeatApp. The colormap displays the WBGT data for heat stress. The AI Chatbot on the right of the figure is named “Sol”, the Spanish word for “sun.” The green camera button in the lower right corner is for taking a screenshot of the colormap, which will be interpreted by the chatbot. For information on the functions of other buttons on this interface, see Bravo et al. (2026). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

protocol with in-person focus groups of farmworkers is employed to evaluate the chatbot's perceived effectiveness, and usability in communicating heat risk information to farmworkers. Metrics include user feedback and use case examples. Finally, the results of the user testing are analyzed to assess and update the chatbot's functionality and usability. This study addresses critical gaps in environmental risk communication, exploring the potential of CAI to improve heat safety communication for vulnerable populations, and offers valuable insights into the challenges and opportunities of deploying LLM-assisted data visualization in high-stakes public health contexts.

The study area

The evaluation of the iHeatApp focuses on the Imperial Valley in southeastern California's Imperial County (Fig. 2), where 85% of residents identify as Hispanic/Latinos and nearly 31% are foreign-born (Tinkler et al., 2025), reflecting cultural and economic ties to Mexico. As of 2022, the county's population was approximately 179,200, with a poverty rate of 21.2%, well above the California average (U.S. Census Bureau, 2022). Imperial County is one of California's leading agricultural hubs, though its farmworkers face significant occupational health risks. Agriculture-related death rates are estimated to be 20 times higher than those of U.S. civilian workers, driven by long hours, high physical demands, and frequent exposure to extreme heat (Jackson and Rosenberg, 2010). Imperial County's semi-arid desert climate leads to some of the highest summer temperatures in California, contributing to consistently elevated rates of heat-related illnesses (Heinzerling et al., 2020). Several key towns, including Brawley, El Centro, and Calxico, have been designated as Disadvantaged Communities (DACs) by CalEPA due to heightened environmental burdens and socioeconomic vulnerabilities (California Environmental Protection Agency, 2022). With

extreme heat ranking as the leading cause of weather-related deaths nationally (NOAA, 2024), the convergence of heat exposure, poverty, and agricultural labor in this region highlights the urgent need for accessible, localized tools to protect farmworker health.

Implementation

The forecast data of Wet Bulb Globe Temperature (WBGT)

Wet Bulb Globe Temperature (WBGT) is a widely used index for assessing heat stress risk in outdoor environments, incorporating the effects of temperature, humidity, solar radiation, and wind (Villero, 2024). We used WBGT forecast data directly from the NOAA National Blend of Models (NBM), a statistically postprocessed, multi-model ensemble product that combines high-resolution numerical weather prediction outputs to provide calibrated and downscaled guidance (Hamill et al., 2017). The NBM is developed and maintained by the National Weather Service and made publicly available through the AWS Open Data Registry (NOAA, 2025).

We accessed WBGT data through the Herbie Python package (Fig. 3), an open-source tool that streamlines retrieval of several recent and archived numerical weather prediction models outputs from different cloud archive sources (Blaylock, 2024), including the NBM forecast fields. Forecasts were downloaded for a bounding box surrounding California's Imperial Valley, with a horizontal resolution of 2.5 km and hourly time steps extending up to 36 h into the future. The current application presents WBGT forecast values and does not display forecast uncertainty or probability ranges. As with all weather forecasts, WBGT values should be interpreted as guidance rather than exact future observations.

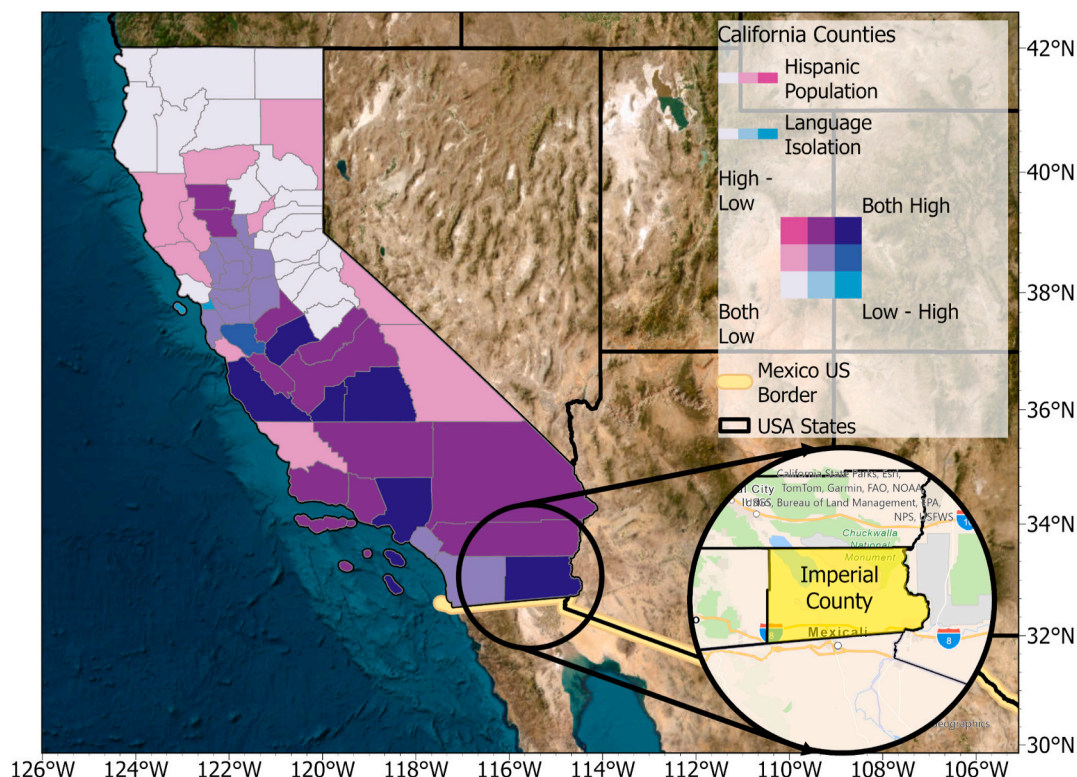


Fig. 2. Study area for implementation and evaluation of the iHeatApp bilingual AI chatbot application: Imperial County, CA, USA (yellow polygon in the bottom right-hand corner). The bivariate map shows where the Hispanic population (%) and language isolation or non-English speaking individuals (%) are the highest (dark purple) and the lowest (light pink) in California. In Imperial County, 85.6% of the population is Hispanic, and 23.8% are non-English speaking, the highest in the state. Source: <https://hdpulse.nimhd.nih.gov/data-portal/home>. The area's agricultural economy and frequent extreme heat events make it a key location for farmworker heat safety efforts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

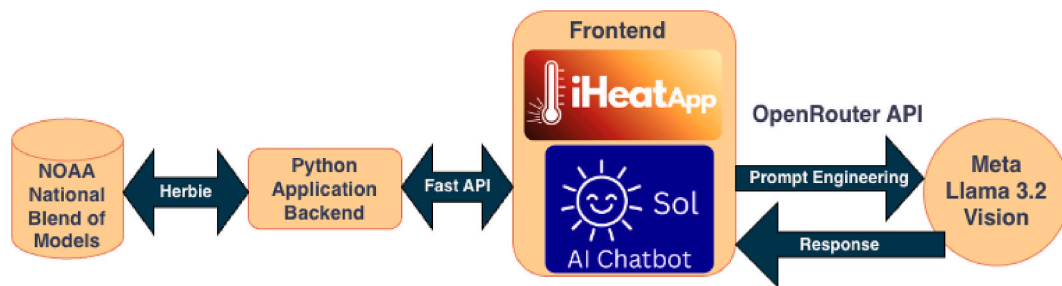


Fig. 3. The AI Chatbot system architecture on the iHeatApp platform illustrates the integration of WBGT forecast data and chatbot functionality. Forecast data from NOAA National Blend of Models are retrieved, processed, and delivered to the application frontend, where users interact with the embedded AI chatbot “Sol” powered by LLaMA 3.2 Vision.

Application interface

The chatbot is embedded within a full-stack, interactive web application designed to communicate real-time WBGT forecast data to end users through an accessible, map-based interface, called iHeatApp (Bravo et al., 2026). The frontend, developed in React.js, uses Deck.gl for high-performance geospatial rendering over dynamic basemap options (e.g., OpenStreetMap, Google Streets, Carto Light). Users interact with WBGT forecasts via a time slider, which allows navigation through 36 h of forecast data, and can locate specific areas using search and optional GPS-enabled location tools. The interface includes bilingual support (English and Spanish) and is designed to be mobile-responsive for convenient use on both desktop and mobile devices. Because the detailed design and evaluation of the iHeatApp interface are described in Bravo et al. (2026), the present paper focuses on the integration of WBGT forecast information with the bilingual AI chatbot, Sol. In the current interface, the gauge provides the categorical WBGT risk interpretation for the selected location, while the color map shows spatial variation in WBGT across the Imperial Valley.

The backend, implemented with FastAPI in Python, accesses the precomputed WBGT forecasts through the Herbie Python package. Forecast data are preprocessed into formats optimized for web use, including map tiles for visualization and structured JSON responses containing WBGT values and metadata.

To enhance user interpretation, a gauge chart displays current WBGT conditions at the user's selected location, categorized using regional heat safety thresholds developed for the general population and adopted by the National Weather Service (Grundstein et al., 2015). The application is deployed on San Diego State University servers, with the React frontend statically served through the FastAPI backend (Fig. 3).

Chatbot design and implementation

The chatbot, named “Sol”, was developed as a conversational tool to assist users in interpreting WBGT forecast data and understanding heat stress risks. It was initially powered by the LLaMA 3.2 Vision 11B Instruct large language model (Meta AI, 2024), accessed through the OpenRouter API (OpenRouter, 2025), which enables both text-based and image-based querying. This multimodal capability allows users to either submit written questions or upload screenshots of the forecast application interface, with the model interpreting both the textual data and the spatial distribution of forecasted heat risk. While LLaMA 3.2-Vision powered the initial version of “Sol”, the system was built with flexibility. Through OpenRouter, the chatbot can be seamlessly connected to newer, more advanced LLMs as they become available, ensuring that “Sol” remains aligned with state-of-the-art capabilities. The chatbot operates in a bilingual mode, supporting both English and Spanish interactions. LLaMA 3.2-Vision was selected for this case because it was accessible for development and supported the two functions most important for Sol's initial design: bilingual conversation and screenshot-based interpretation of the iHeatApp interface. The

present study does not compare performance across alternative large language models, since the focus is on the integration of WBGT forecast data with a bilingual chatbot for farmworker heat-risk communication rather than on model benchmarking. The chatbot user interface includes both English and Spanish welcome messages (Figs. 4(a) and 4(b)).

To ensure relevant, accurate, and understandable responses, we employed prompt engineering strategies that provide the model with structured contextual information. This includes detailed descriptions of WBGT, its relevance to occupational heat stress, clear guidelines for outdoor activity recommendations based on established WBGT risk categories, as well as the current WBGT value at the selected location. The chatbot is designed to simulate a domain-specific assistant, referred to in the system prompt as Sol, who specializes in explaining WBGT forecasts to non-expert users in the Imperial Valley region (NOAA, n.d.).

The prompt architecture consisted of two layers. A persistent system prompt provided the model with foundational instructions, including an overview of WBGT, the geographic coverage area, temporal resolution of the forecast data, and categorical heat-risk thresholds aligned with the OSHA and the National Institute for Occupational Safety and Health (NIOSH) heat stress recommendations, as well as regional public health thresholds adopted by the National Weather Service (Grundstein et al., 2015; NIOSH, 2016; OSHA, 2024). A supplementary vision prompt was dynamically constructed when users submit screenshots, containing location-specific WBGT values, forecast time details, and a request for activity recommendations tailored to current heat risk conditions.

To reduce the risk of hallucinations and prevent the dissemination of incorrect information, particularly given the sensitive public health implications, the prompts incorporated explicit instructions discouraging speculation and encouraging cautious responses. The system prompt directed the model to avoid generating responses when uncertain, to refrain from exaggeration, and to use plain, accessible language when explaining scientific terms. The model was also explicitly instructed to limit responses to brief, action-oriented guidance and to avoid making recommendations beyond the provided WBGT data and categories.

Recent work on AI-enabled climate early-warning systems emphasizes that tools used for risk communication in vulnerable communities need to be transparent and developed responsibly (Reichstein et al., 2025). In one widely cited case, a healthcare algorithm used cost as a stand-in for medical need and ended up providing Black patients less care than White patients with the same level of illness (Obermeyer et al., 2019). Sol's guardrails, which limit responses to verified WBGT categories and established heat-safety guidance instead of open-ended inference, are built to avoid that kind of failure. For Sol, the prompt was designed to keep responses grounded in the WBGT forecast shown in the app and to explain heat risk in plain language. The prompt also instructed the model not to make recommendations beyond the available WBGT data and risk categories. However, prompt engineering cannot fully prevent errors. If a user provides a WBGT value that conflicts with the app display, the chatbot may treat that statement as part of the conversation. For this reason, Sol assists interpreting the forecast

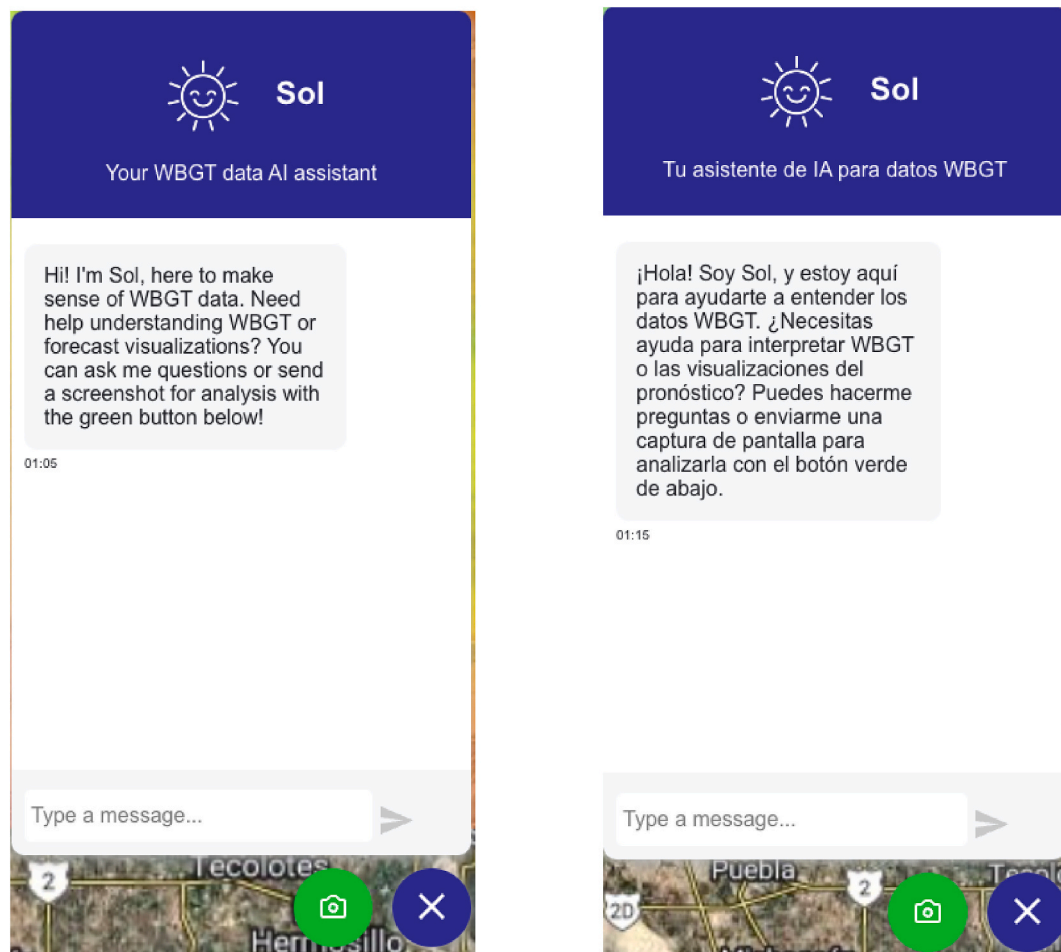


Fig. 4. The screenshots of the AI chatbot's bilingual welcome messages: English (Fig. 4(a)) and Spanish (Fig. 4(b)).

conditions shown in iHeatApp and delivering established heat-safety recommendations, while the WBGT gauge and heatmap remain the primary sources for the selected heat-risk conditions.

This multi-layered prompting strategy served as one safeguard to enhance the reliability of the chatbot's responses, acknowledging the importance of climate health information and the need for conservative, fact-based communication. The chatbot was integrated into the web application interface via a React Chat Widget, enabling interaction alongside the map visualization, forecast time slider, and location-specific WBGT data display.

Focus groups for feedback

To evaluate the clarity, tone, and perceived usefulness of the AI-powered chatbot integrated into iHeatapp, we conducted semi-structured user feedback sessions in partnership with Líderes Campesinas (please see <https://liderescampesinas.org/>) across four dates in May and July 2025. Three in-person sessions took place in indoor community spaces selected by our partner to ensure participant comfort. The sessions were facilitated in Spanish, with interpretation support from a community representative. In total, we gathered feedback from 18 unique farmworkers. These sessions followed an iterative, human-centered design process. Rather than evaluate a final product, feedback from each round shaped changes to Sol's phrasing, persona, and interface before the next round of testing. Each session lasted approximately 60 to 90 min. Participants engaged directly with the chatbot interface on their own mobile devices in structured scenarios (e.g., asking about the heat forecast or what clothing to wear) and were

invited to describe their understanding, expectations, and impressions (Fig. 5). The sessions were not A/B tests or controlled experiments; participants were guided through similar example tasks but were also encouraged to ask their own questions and interact with Sol freely. Verbal consent was secured and audio logs were used to document the process. We also recorded the dialogue between participants and the chatbot for further analysis. Participants provided detailed feedback on language clarity, persona design, button labeling, and message tone. All feedback was anonymized and analyzed qualitatively using participant comments, audio logs, field notes, and chatbot dialogue records to identify recurring themes to improve Sol's response style, accuracy, and multilingual accessibility in future versions of the tool.

Before conducting the user feedback sessions, we developed a short tutorial to introduce participants to the iHeatApp and its integrated chatbot. The goal of this tutorial was to provide users with clear instructions on how to navigate the application, access WBGT forecasts, and interact with the bilingual AI assistant, Sol. By familiarizing participants with the basic functions of the tool, we ensured that feedback sessions focused on evaluating usability, clarity, and perceived value, rather than on initial orientation. The following tutorial content was presented to users prior to their engagement with the system.

Feedback session user's manual

The iHeatApp features a built-in bilingual AI assistant, Sol, that helps users interpret WBGT forecasts and receive personalized recommendations for reducing heat stress risk. The chatbot is accessed through the speech-bubble icon in the lower right corner of the application, and



Fig. 5. Farmworker using the iHeatApp during a feedback session. The mobile display shows the WBGT gauge in Spanish (68.0 °F) with risk categories from *Seguro* (Safe) to *Extremo* (Extreme).

supports both English and Spanish.

Once opened, users can type natural-language questions such as “What is the WBGT for Brawley?” or “¿Qué ropa debería usar hoy?”. Sol responds with plain-language explanations that often include the WBGT value, its corresponding risk category, and relevant safety recommendations, such as hydration, rest breaks, and clothing guidance.

The chatbot also supports visual queries. A green camera icon allows users to capture their current WBGT forecast view and send it directly to Sol for analysis. For example, after selecting a location and forecast time on the map, a user can send a screenshot for tailored, location-specific recommendations on safe work practices.

Follow-up questions are supported, so users can refine or expand their inquiries without repeating location or time details. Guardrails are in place to reduce misinformation, and explanations of WBGT categories are included to improve clarity. While Sol is not a replacement for official occupational safety advice, it offers an accessible, mobile-friendly way to make informed decisions about heat exposure in the field.

Findings from user engagement

Case examples

The detailed chatbot Sol interaction and recommendations are shown in Fig. 6, and Fig. 7 demonstrates a real-world use example of the chatbot by farmers from a user feedback session. A farmworker preparing for a mid-afternoon shift selects the worksite location just outside of Brawley, within iHeatApp and adjusts the forecast time to 10:00 a.m. on September 24, 2025, when peak heat is expected. To receive tailored recommendations, the user captures a screenshot of the heatmap and sends it to “Sol,” the integrated AI chatbot by clicking the green button to automatically generate the interpretation.

The chatbot analyzes the forecasted Wet Bulb Globe Temperature (WBGT) for the selected location and time, interprets the WBGT category, and provides a concise risk assessment. The response includes recommended protective measures such as adjusting work–rest cycles

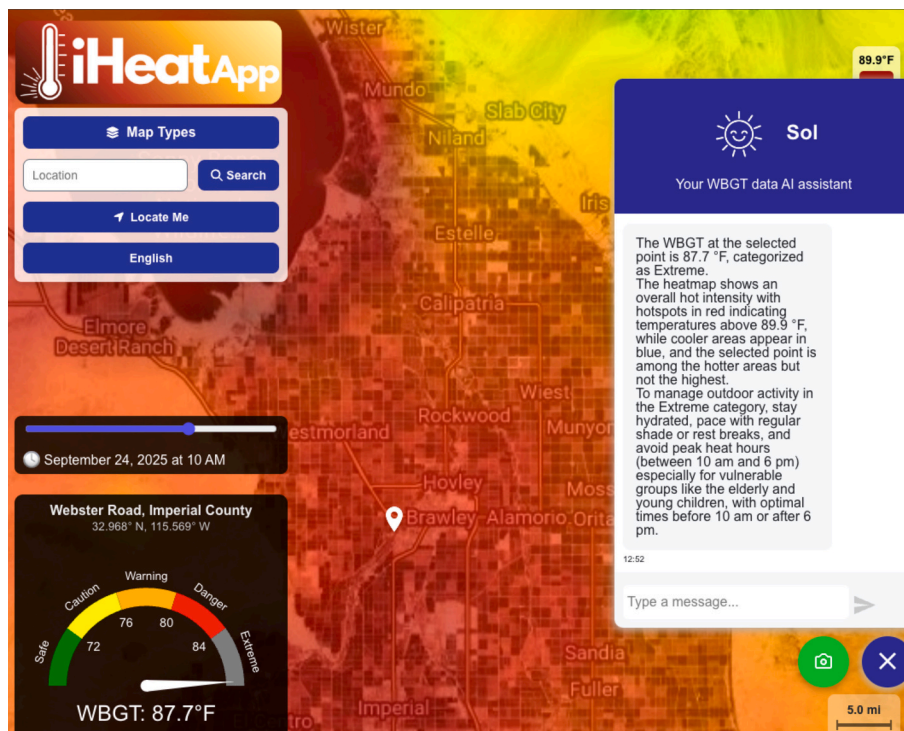


Fig. 6. The text in the white box shows the AI chatbot Sol's interpretation of the WBGT forecast for 10:00 a.m. on September 24, 2025.

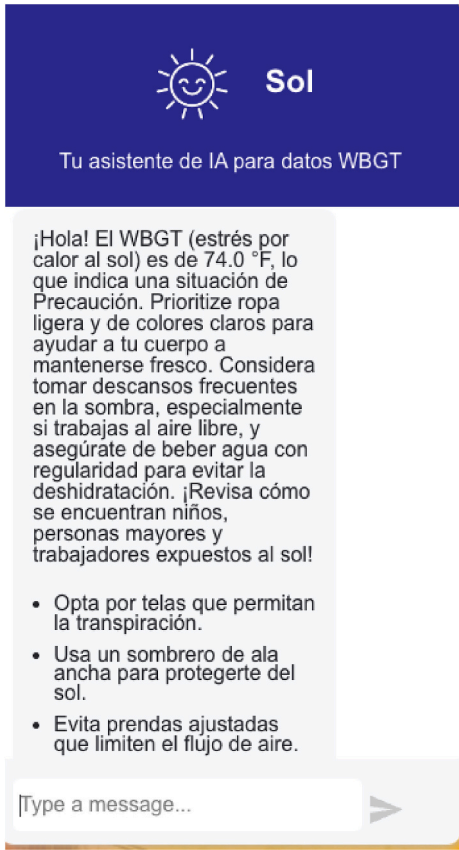


Fig. 7. Chatbot response to a user asking what clothes they should wear based on forecasted conditions. The English translation of the response is “Hello! The WBGT (sun heat stress) is 74.0°F, which indicates a Caution condition. Prioritize lightweight, light-colored clothing to help keep your body cool. Consider taking frequent breaks in the shade, especially if you work outdoors, and be sure to drink water regularly to avoid dehydration. Check on children, the elderly, and workers exposed to the sun! Choose breathable fabrics. Wear a wide-brimmed hat to protect yourself from the sun. Avoid tight-fitting clothing that restricts airflow.”

and increasing water intake. This example highlights the system's ability to combine visual climate data with natural language interpretation, transforming a static forecast into actionable, context-specific guidance that supports heat safety in agricultural work.

In another instance, a worker directly asked, “¿Qué ropa debería usar hoy?” (“What clothes should I wear today?”). Drawing on the forecasted WBGT of 74.0 °F, Sol provided attire recommendations in Spanish (Fig. 7), emphasizing lightweight, light-colored clothing to help keep the body cool, breathable fabrics, and a wide-brimmed hat for sun protection. The chatbot also advised avoiding tight-fitting garments that restrict airflow, along with taking frequent breaks in the shade and drinking water regularly to prevent dehydration. Participants affirmed the usefulness of these tailored suggestions; as one farmworker noted, “If I asked it what kind of clothes I should wear, it even told me what kind of hat, glasses, and everything. It answered me really well. It replied with a large text”. This example illustrates how the chatbot delivers both localized, condition-specific safety advice and culturally relevant recommendations in the user's preferred language. These recommendations were consistent with the OSHA Heat Stress Guide (OSHA, 2024).

Themes from participant questions

During the user feedback sessions, interactions between farmworkers and the chatbot revealed three dominant themes: (i) WBGT and heat forecasting, (ii) clothing and protective measures, and (iii) broader weather and contextual factors (Table 1). Participants frequently sought

Table 1
Example chatbot questions grouped into three key themes reflecting farmworkers' needs for localized heat guidance, safety tips, and weather context.

Theme	Example Questions
WBGT & heat forecasting	What is WBGT for Brawley?; How hot will it be today?; What time will it start getting cool?; What does precaution mean?; What is WBGT?; What category is this WBGT?
Clothing & protective measures	What clothes should I wear today?; What clothes to wear in 100+ degree weather?; What do you recommend to wear on a humid day in summer?
Weather & contextual factors	Is it going to be windy today?; Will it be cloudy tomorrow in Imperial Valley?; What is the temperature today?; How hot is it today?

real-time guidance on local heat risk, safety measures, and clothing recommendations. This illustrates their need for interpretable, actionable data that supports their daily decisions in the field. The chatbot consistently responded in both English and Spanish, offering explanations of WBGT risk levels and reinforcing precautionary behaviors such as hydration, shade breaks, and appropriate attire. These interactions suggest the chatbot served as a useful tool for communicating heat-related risks in a way that was both culturally and occupationally relevant.

To identify the main themes, we documented all questions participants submitted to the chatbot during the sessions. Questions were recorded through field notes, photographs of participants' mobile screens, and transcribed translations from Spanish to English. We then applied an iterative, manual coding process following the qualitative framework outlined in Bernard (2017) to identify recurring patterns in the questions asked. No coding software was used.

Lessons learned

This study presented the development and deployment of a bilingual AI chatbot, named “Sol”, integrated into a web-based application (iHeatApp) for interpreting WBGT forecasts and supporting heat risk awareness among farmworkers in California's Imperial Valley. The system combined real-time climate data retrieval, localized heat stress visualization, and interactions with a large language model, prompt-engineered to improve accuracy and reliability. The chatbot was developed by an interdisciplinary team of data scientists, climate specialists, and public health experts, reflecting the importance of bridging technical innovation with domain expertise to address agricultural health challenges. This tool was designed to connect live WBGT forecast data with plain-language, bilingual heat-safety guidance for agricultural workers, managers, and government. The innovation of Sol lies in this integration: forecast data are not only visualized on a map, but also interpreted through a conversational interface that is tailored to the language, context, and communication needs of a farmworker community that is vulnerable to extreme climate conditions.

User feedback suggested that the chatbot addressed information needs related to WBGT forecasts, protective measures, and broader weather context, making heat risk communication more accessible and actionable in both English and Spanish. Because the feedback sessions were conducted during active development, these findings should be interpreted as evidence of perceived clarity, accessibility, and relevance, rather than evidence of long-term adoption or changed work decisions. These results demonstrate the system's technical promise and its potential to support farmworker safety by translating complex environmental forecasts into practical guidance. This work illustrates how AI technologies can be leveraged in agriculture to provide culturally and linguistically tailored support to vulnerable labor populations. The integration of conversational AI with weather and climate services represents a significant step toward proactive, technology-driven approaches to occupational safety in outdoor agricultural settings.

Future work will focus on training domain-specific models tailored to

agricultural and climate health contexts, curating and annotating larger datasets to improve response precision, and expanding the system to address other environmental hazards such as wildfire smoke and air quality. By continuing to refine and broaden the platform, we aim to create a scalable, multilingual tool for environmental risk communication that supports vulnerable outdoor labor populations across diverse regions.

The deployment of a bilingual chatbot for WBGT interpretation in an agricultural context highlights how conversational AI can bridge gaps in climate-health communication. The system's bilingual capacity addressed a core accessibility challenge in the Imperial Valley, where much of the workforce speaks Spanish as a primary language. This feature not only expanded reach but also allowed for culturally relevant exchanges, potentially increasing trust and engagement compared to static heat safety bulletins.

Flexibility of a large language model presents inherent challenges. While users benefited from being able to phrase questions naturally and receive tailored responses, this open-ended interaction space increases the possibility of incomplete or inaccurate information. The use of prompt engineering and guardrails reduced, but did not eliminate this risk. In real-world environmental health applications, maintaining user trust requires both transparency about limitations and strategies to verify outputs in authoritative sources. A limitation of this study is that we did not formally and quantitatively compare large language models, prompt designs, or hallucination rates. Future work should test candidate models using standardized WBGT scenarios and evaluate how different prompt and guardrail designs perform with both accurate and adversarial inputs. Next versions should also include formal adversarial testing with contradictory WBGT values, misleading prompts, ambiguous screenshots, and requests outside the available forecast data.

The visual interface also has limitations. The heatmap and gauge categories do not always communicate risk in the same way, since the map colors show spatial variation across the forecast domain while the gauge displays the WBGT risk category for a selected location. This difference may create confusion for some users and should be addressed in future interface refinements. Future versions should also communicate forecast uncertainty in ways that are understandable to non-specialist users, particularly when WBGT values are near risk-category thresholds. Possible approaches include forecast ranges, confidence language, or conservative recommendations when uncertainty could affect the assigned risk category.

The results also point to opportunities for greater domain specificity and adaptation of this technology to other regions. Current responses rely on a general-purpose model guided by prompts; however, a model trained or fine-tuned on agricultural safety, localized climate data, and region-specific work practices could further reduce ambiguity. Such tailoring could also enable hyper-local recommendations, such as guidance for specific crops, tasks, or seasonal conditions, that go beyond general WBGT categories. The architecture could be adapted for use in other regions where WBGT forecast data are available, but it would not be enough to simply redeploy the same software. Each community has different heat-risk thresholds, work conditions, languages, levels of digital access, and applicable regulations. Future deployments should therefore be developed with local partners and adjusted so that the chatbot's language and recommendations fit the community it is intended to serve. Later updates could make Sol's recommendations more personalized. Optional follow-up questions about work intensity, time already spent in hot conditions, acclimatization, and access to shade or water could help tailor guidance to the individual while keeping responses grounded in established heat-safety recommendations.

Climate services literature has pointed out a distinction between producing climate information and using it in decision support (Findlater et al., 2021). WBGT forecasts for the Imperial Valley were publicly available before this project, but public availability does not necessarily make information accessible or easy to use. Sol was designed to help bridge that gap by connecting users to existing climate data and

established heat guidance in a form that is easy to interpret, bilingual, and tailored to the regional and cultural context. More broadly, conversational tools like this could help climate services connect people with existing climate information by translating data and established policy into language and formats accessible to the communities who need them.

Recent work has suggested evaluating AI-enabled climate services based on whether they are useful to intended users, trustworthy, and developed in ways that reflect community needs (Williams et al., 2026). Sol's bilingual, plain-language design, structured prompting, safety guardrails, and development with Líderes Campesinas all reflect these goals. At the same time, the absence of a verified knowledge base or retrieval-grounded system, as used in some other climate-service chatbots (Kuznetsov et al., 2025), remains an important limitation. For climate-service practitioners, the broader implication is that conversational AI does not need to replace existing forecast products or outreach programs to be useful. A tool like Sol can instead add to them by interpreting and communicating information already in circulation within heat-illness prevention, extension, or community outreach efforts, so long as participatory development, local adaptation, and culturally appropriate safeguards stay central to how it is deployed (Terrado et al., 2023).

The process used to build Sol mattered as much as the underlying model. Across four rounds of in-person feedback sessions with Líderes Campesinas, farmworkers shaped Sol's persona, response scripts, and interface, instead of just creating a finished product. This approach fits the broader participatory research program we have built with Líderes Campesinas in this region (Ciborowski et al., 2026), the co-production principles used in the climate services literature (Vaughan and Dessai, 2014; Vincent et al., 2018), and the older public-health tradition of community-based participatory research those principles draw on (Israel et al., 1998). Other climate service teams could use the same approach and build *with* the communities meant to use the tool, not *for* them.

While the present system cannot guarantee perfect accuracy, its role as an accessible, on-demand source of heat safety information is clear. The integration of real-time climate data, bilingual communication, and context-sensitive recommendations represents a promising approach for supporting occupational safety in high-heat environments. Continued refinement and integration with trusted public health messaging could enhance both reliability and adoption in the field. As one participant remarked, "*Sol's purpose is clear from her first welcome message*", reflecting how users quickly recognized the chatbot's role in delivering practical and trustworthy guidance.

CRedit authorship contribution statement

Riley Rutan: Writing – original draft, Software, Methodology. **Miguel Á. Bravo:** Writing – review & editing, Software, Resources, Investigation. **Corrie Monteverde:** Writing – original draft, Validation, Project administration, Investigation, Data curation. **Ryan P. Lafler:** Methodology. **Trent Biggs:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Fernando De Sales:** Writing – original draft, Resources, Data curation. **Ana Solorio:** Project administration. **Briana Toji Ruiz:** Project administration. **Samuel S.P. Shen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data and computer code for this paper are freely available at: https://github.com/rutan/SDSU_Heat_App.

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