BAMS In Box

The Hawai'i Climate Data Portal (HCDP)

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ABSTRACT: The Hawai'i Climate Data Portal (HCDP) is designed to facilitate streamlined access to a wide variety of climate data and information for the State of Hawai'i. Prior to the development of the HCDP, gridded climate products and point datasets were fragmented, outdated, not easily accessible, and not available in near–real time. To address these limitations, HCDP researchers developed the cyberinfrastructure necessary to 1) operationalize data acquisition and product production in a near-real-time environment and 2) make data and products easily accessible to a wide range of users. The HCDP hosts several high-resolution (250 m) gridded products including monthly rainfall and daily temperature (maximum, minimum, and mean), station data, and gridded future projections of rainfall and temperature. HCDP users can visualize both gridded and point data, create and download custom maps, and query station and gridded data for export with relative ease. The "virtual station" feature allows users to create a climate time series at any grid point. The primary objective of the HCDP is to promote sharing and access to data and information to streamline research activities, improve awareness, and promote the development of tools and resources that can help to build adaptive capacities. The HCDP products have the potential to serve a wide range of users including researchers, resource managers, city planners, engineers, teachers, students, civil society organizations, and the broader community.

SIGNIFICANCE STATEMENT: The Hawai'i Climate Data Portal (HCDP) is an open-source data platform designed to provide easy access to climate data and information for the State of Hawai'i. The HCDP contains both station data and historical and future maps of rainfall and temperature. These high-resolution (250 m) maps are updated in near–real time and available for streamlined visualization and download. The HCDP fills a critical need for a centralized clearinghouse of climate data in the State of Hawai'i. HCDP data can be used to make resource management decisions and to raise awareness of observed and projected changes to the climate system. Many ongoing projects are leveraging HCDP data to develop models and decision support tools to improve adaptive capacities across the state.

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1. Data portal purpose and design

The effects of climate change, including higher temperatures (McKenzie et al. 2019), increased drought magnitude and duration (Frazier et al. 2022), decreases in rainfall (Longman et al. 2015; Frazier and Giambelluca 2017), and more severe extreme weather events (Nugent et al. 2020), are threatening both human and natural systems in Hawai'i. The need for high-quality, spatially explicit climate data and other information is becoming increasingly important to a wide range of users focused on protecting these systems (Oakley and Daudert 2016). Researchers, state and federal government agencies, natural resource managers, farmers, ranchers, and many communities across the state are trying to better understand the magnitude of climate change impacts and are looking for ways to mitigate and adapt to observed and projected changes so that resources and livelihoods can be better protected (Longman et al. 2022a,b).

Meteorological observations obtained from weather stations across the state are essential for improving our understanding of climate and for developing tools and resources to help make planning and climate adaptation decisions. Despite the importance of high-quality meteorological observations, obtaining and using data have, until now, been difficult and one of the most challenging aspects of any research project has been the identification, acquisition, and quality control of data. In Hawai'i, climate data are available through several sources including independent researchers, local, state, and federal agencies, and large electronic repositories such as the National Centers for Environmental Information (NCEI; https://www.ncei.noaa.gov/) (Longman et al. 2018). Some data sources are not publicly available, and others may require technical skills or expertise to access the data. Data that are available through open-source platforms (such as NCEI) can be accessed with relative ease but are not comprehensive, may contain erroneous values not captured during quality control, and are often not available in near–real time (e.g., next day). In addition, gridded climate products available for the conterminous United States (CONUS) such as PRISM (Daly et al. 1994) or gridded surface meteorological (gridMET) (Abatzoglou 2013) datasets often do not produce products for Hawai'i (Basile et al. 2024). This lack of available data can delay or inhibit timely and informed decision-making, as well as implementation of climate adaptation actions (Keener et al. 2022; Frazier et al. 2023; Basile et al. 2024).

Several previous efforts have compiled station observations using a wide array of data sources and produced gridded climate products for Hawai'i (Giambelluca et al. 2013; Frazier et al. 2016; Longman et al. 2018, 2019; Lucas et al. 2022; Kodama et al. 2024). However, after such projects conclude, the dataset produced has a distinct end date. By the time these products are published and made available, they are out of date for many purposes. Researchers wanting to utilize the most comprehensive and up-to-date data in their analyses are faced with the same recurring challenges mentioned above. The lack of a central data repository containing a comprehensive archive of climate data that are easily accessible and updated in

near–real time is therefore essential to improving the efficiency in which data are accessed, processed, and made available to end users.

To address this gap, the Hawai'i Climate Data Portal (HCDP; https://www.hawaii.edu/climate-data-portal/) was created to capture and store near–real time climate data and to produce quality-controlled point and gridded datasets that are easily accessible to end users. The HCDP provides users with access to a wide range of relevant climate data and information from across the state via an easy-to-use, open-source data repository. The objective of this paper is to introduce readers to the datasets, resources, and function features available on the HCDP interface and to discuss future opportunities for additional products.

2. Near-real-time climate mapping

Between 1 March 2022 and 1 April 2024, the HCDP ingests data from 261 stations measuring rainfall and 179 stations measuring temperature (Fig. 1) many of which continue to report in near–real time. Multinetwork weather stations are equipped with internal loggers and systems for mobile communication, and raw data are transferred via satellite or cell phone transmission to respective federal data repositories where internal quality control procedures are implemented. The primary data repositories include Hydrometeorological Automated Data System (HADS), the Meteorological Assimilation Data Ingest System (MADIS), and the National Weather Service (S1 in the online supplemental material).

Climate data from these repositories are extracted and stored on the HCDP database (Cleveland et al. 2018) where they are processed to a standard format, including converting data to the International System of Units (SI), aligning date and time stamps, assigning "NA" to all missing values, and aggregating subdaily data to the daily time step. Daily data are screened for large erroneous values using previously published and variable-specific

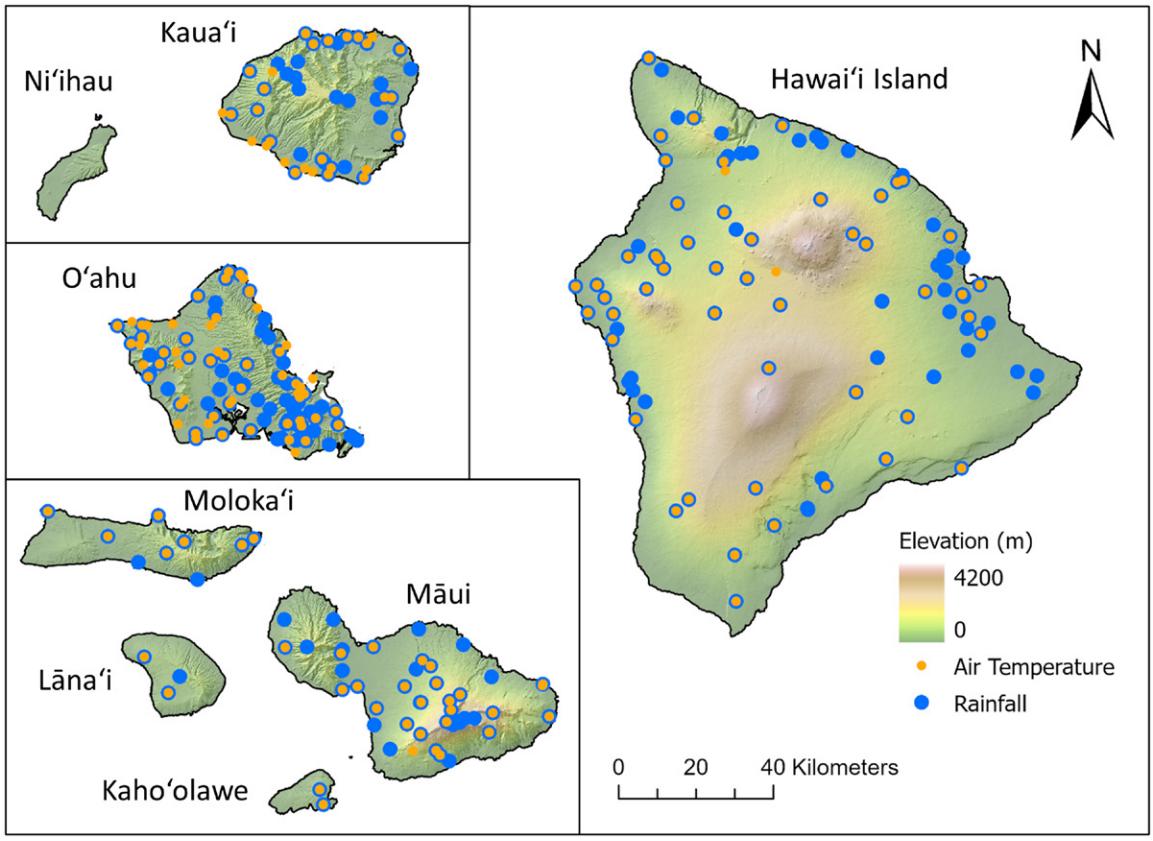

Fig. 1. Locations of climate stations accessed by the HCDP from 1 Mar 2022 to 1 Apr 2024.

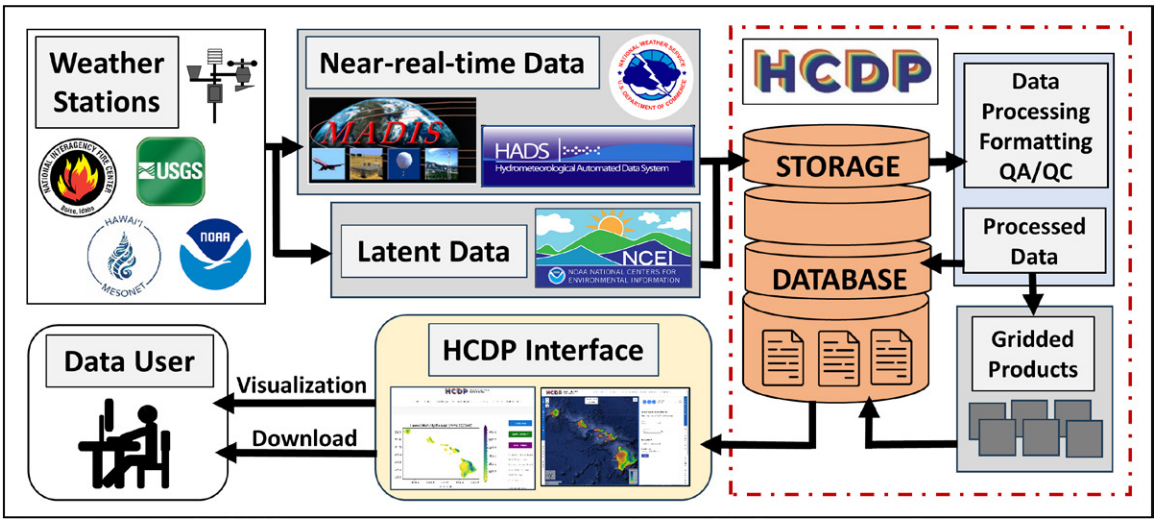

Fig. 2. Schematic view of the HCDP near-real-time workflow.

range limits (Longman et al. 2018). Postprocessed rainfall and temperature data go through an additional variable-specific screening for outliers prior to the production of gridded products as described in previously published work (Lucas et al. 2022; Kodama et al. 2024).

Variable-specific algorithms initiate automatically to produce gridded products at a standard 250-m resolution, which are stored on the HCDP database. The HCDP interface is available to users in near–real time (24-h latency) for the visualization and download of data. The complete workflow (Fig. 2) is executed on the Mana High-Performance Computer (HPC) located at the University of Hawai'i for large multi-time-step batch processing (Merrill et al. 2023) and on the NSF JetStream2 cloud infrastructure for daily and monthly execution (Stewart et al. 2015; Towns et al. 2014).

Workflows for the creation of daily gridded products execute at midnight daily and on the first day of each month for monthly products. Corresponding metadata, i.e., data used to create grids and uncertainty products, are available for each gridded product. When selecting a data download package, users can choose the relevant documentation and uncertainty products to be included in the data package. Gridded products are updated periodically when latent data become available. Latent data are primarily acquired from the NCEI Global Historical Climatology Network (GHCN)-Daily (Menne et al. 2012) or from local nonnetwork observers. Latent data are combined with existing data and put through the same quality control processing described earlier.

3. Available datasets and data query tools

Gridded products available (at the time of this publication) include 104 complete years (1920–2023) of monthly rainfall and 34 years (1990–2023) of daily and monthly temperature maps. Future projections of gridded rainfall and temperature are also available from two climate downscaling products: dynamical downscaling (Zhang et al. 2016a,b) and statistical downscaling (Elison Timm et al. 2015; Elison Timm 2017) for two future emission scenarios (RCP4.5 and RCP8.5; supplemental S2). Station (point) data include 34 complete years (1990–2023) of daily rainfall and temperature (maximum and minimum). All HCDP-generated data products are open source and freely available to noncommercial users via the portal's "Data Access" platform.

Data query tools. The HCDP is an open-access information system, allowing users to query station data based on any number of parameters including variable, period of record, geographic coordinates, station name, elevation, island, and availability of data. The interactive

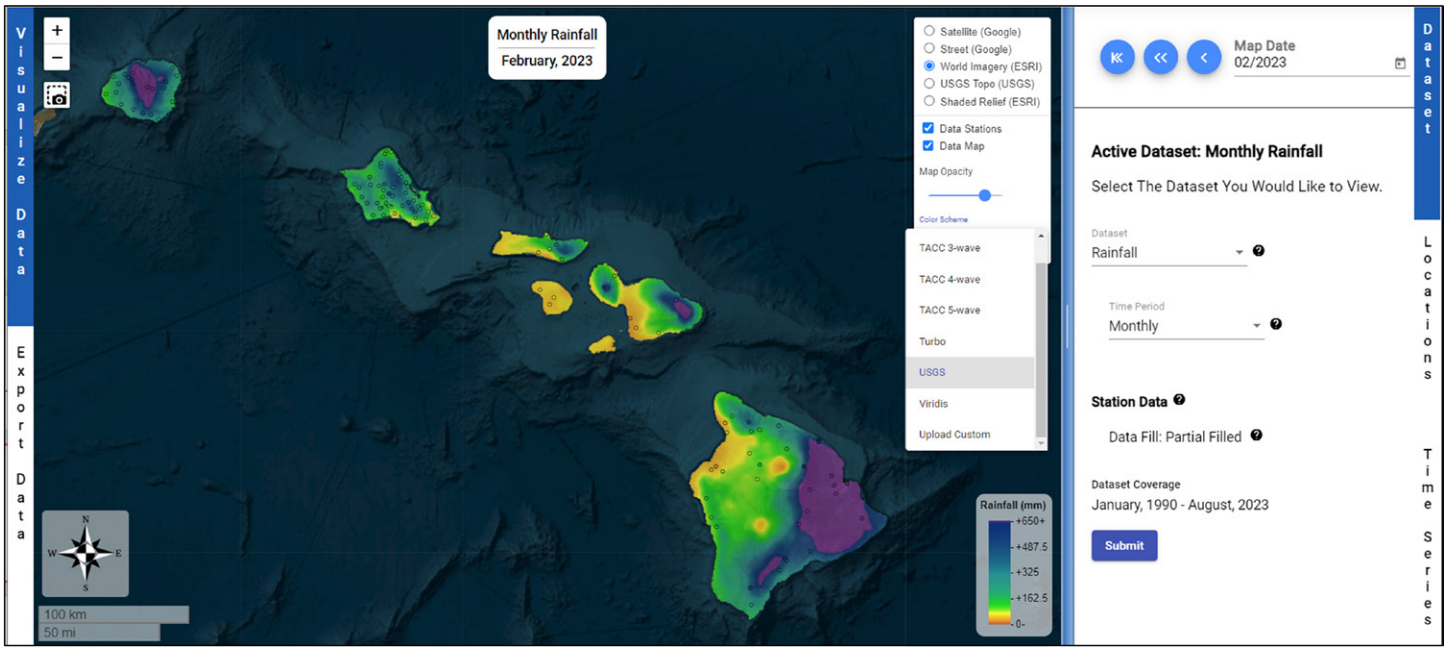

Fig. 3. The HCDP interactive mapping tool allows users to select a dataset and time step (daily or monthly) of interest, customize a map, and then download it as a JPEG.

data tool (Mclean et al. 2021) gives users the opportunity to visualize any gridded climate product in the library and to customize and download the image (Fig. 3). The visualization tool allows users to view digital maps of historical rainfall and temperature, zoom in on areas of interest, select between one of five base maps, select one of six color ramps (or upload a custom color ramp), toggle stations and gridded data on or off, and obtain the associated grid value (metric or imperial units) at any map location. When individual stations are selected, the accompanying metadata are displayed to the right of the image and associated daily and monthly time series are generated. A "virtual station" feature option allows users to create a climate time series by selecting a point anywhere on the map, and corresponding point values across the entire period of record will be displayed in a graph (supplemental S3). Time-series graphs are customizable, can be visualized for any subset of years, and downloaded as an image. The climate data used to generate the plots can be downloaded in a comma-delimited ASCII format.

4. Portal utility and applications

For the first time, researchers in Hawai'i have streamlined access to historical and near-real-time gridded climate products. In Figs. 4 and 5, we highlight examples of how HCDP tools can be utilized to explore climate phenomena. In Fig. 4, we show rainfall for the island of Kaua'i on 15 April 2018 at the station located near Waipā, Hawai'i, where the U.S. 24-h rainfall record was set (Corrigan and Businger 2022), and the record islandwide monthly rainfall for Hawai'i Island during the passage of Hurricane Lane in August 2018 (Nugent et al. 2020). In Fig. 5, we show average daily temperatures in Lāhainā, Maui, on 8 August 2023, the day widespread fires engulfed and destroyed the historic town, and future (end-century) dynamically downscaled projections of temperature for a high-emission pathway (RCP8.5), in a critical bird habitat on the north shore of O'ahu. In these examples, we use different base layers, color ramps, and station information to highlight the range of optimization features available on the HCDP. These examples demonstrate the utility of the available data visualization and data tools. All of the custom maps, time-series figures, and the data used to create the figures can be easily downloaded using the portal's "Export Data" feature.

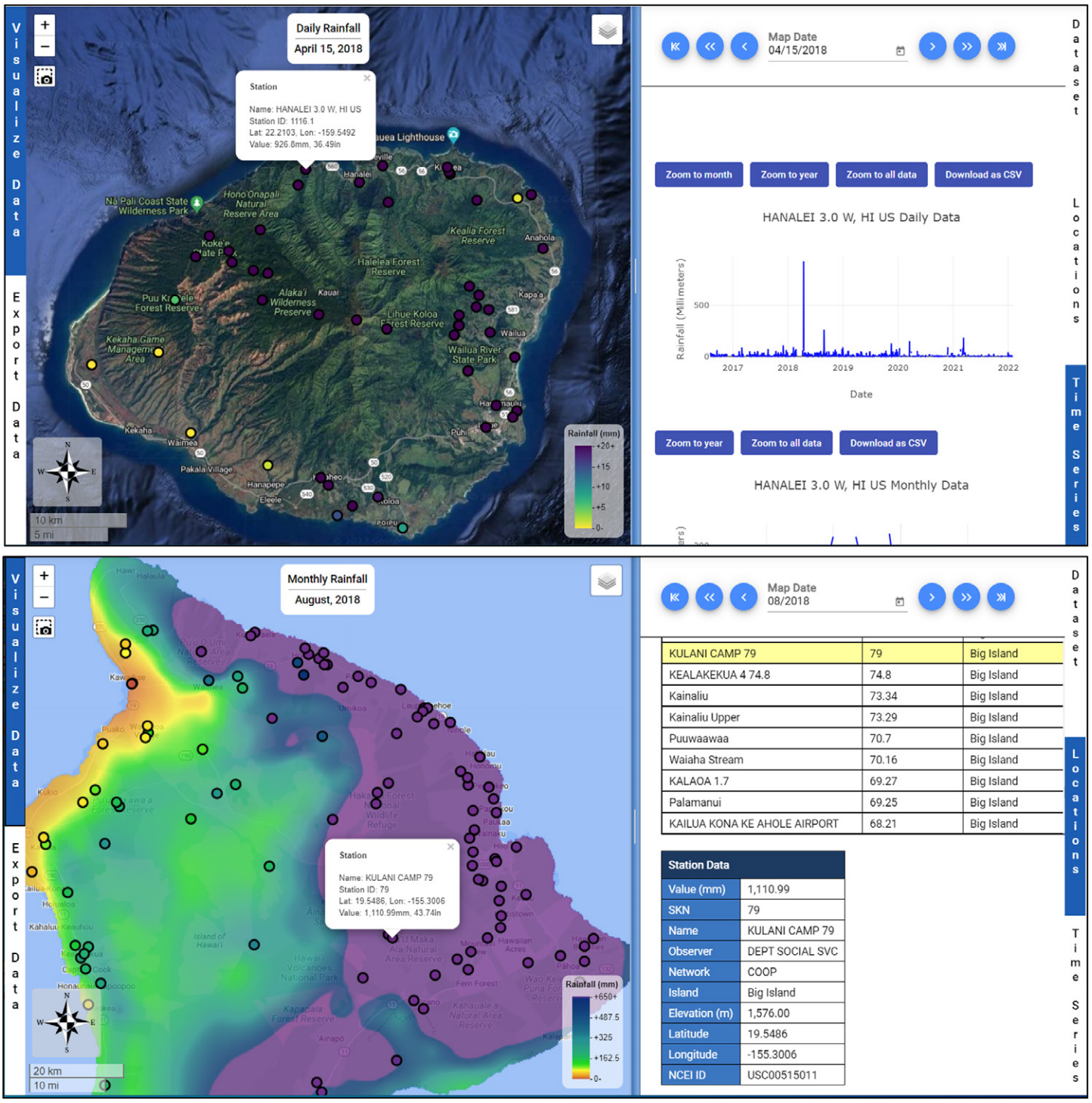

FIG. 4. (top) Visualizing daily station rainfall data on 15 Apr 2018 at Waipā in Halele'a District in the north shore of Kaua'i, and (bottom) visualizing monthly gridded and point rainfall in August 2018 on Hawai'i Island. The top panel shows the "HANALEI 3.0 West" station selected on the map and the associated 7-yr daily rainfall time series; the map is made using a "Satellite" base layer and the "Viridis" color ramp. The bottom panel shows the "KULANI CAMP 79" station selected on the map and the associated metadata displayed to the right; the map is made using the "Street" base layer and the "USGS" color ramp.

Qualitative features of the HCDP. In addition to the numerical data found on the HCDP, the design team has made an effort to include key qualitative elements related to climate in the portal as well. These include a searchable library with over 350 peer-reviewed journal articles and technical reports related to climate and ecological research in Hawai'i and over 250 National Weather Service monthly precipitation summaries which are not otherwise publicly available (supplemental S5).

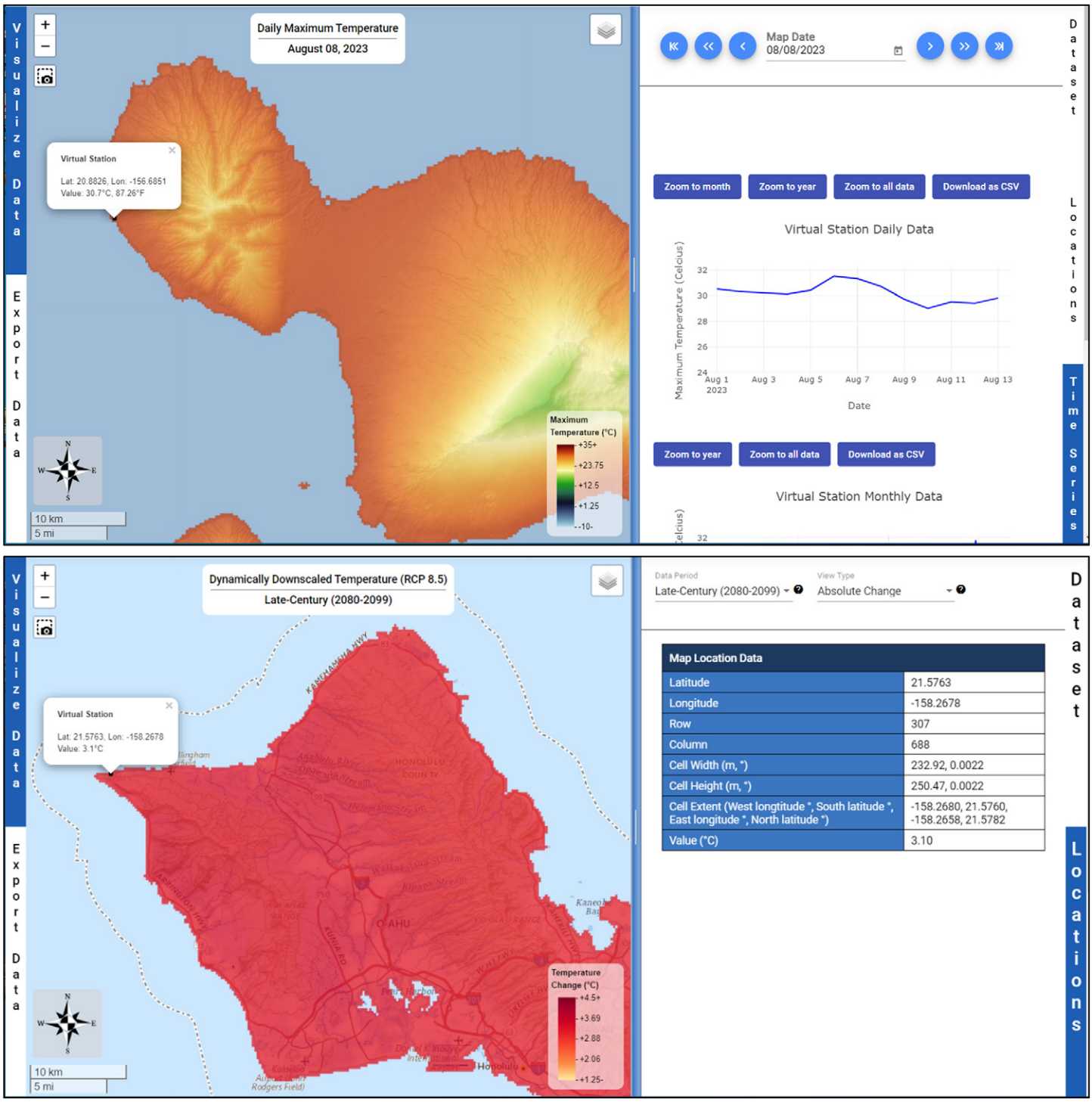

Fig. 5. (top) Visualizing average daily maximum temperatures in Lāhainā, Maui, on 8 Aug 2023, and (bottom) future (end-of-century) annual temperature change for O'ahu. The top panel shows a virtual station point representing an area in Lāhainā, Maui, on the left, and a 14-day custom time series of maximum temperature for this location on the right for 1–13 Aug 2023. The map is made using the "Shaded Relief" base layer and "TACC-3" color ramp, and stations are toggled off. The bottom panel shows future temperature using the dynamically downscaled RCP8.5 projection, shown in units of absolute change. For the point selected on the map, virtual station metadata are shown to the right. The map is made using the "USGS Topo" base layer and the "Diverging" color ramp.

Traditional ecological knowledge (TEK) related to climate is highlighted through the HCDP "Cultural Resources" interface. The Cultural Resources section is developed based on recommendations and contributions from a Native Hawaiian advisory team and various collaborators. At present, this section includes a range of biocultural information related to TEK including a climate glossary of Hawaiian environmental terminology, an array of educational

resources, and highlights of ongoing research projects. An emerging area of research focuses on historical weather and climate as documented in archival Hawaiian language resources including newspapers. This information can be used to inform and communicate with communities regarding climate adaptation and resiliency.

In an effort to keep the community informed, the HCDP team creates a weekly educational post on social media (X and Instagram) accounts (@hiclimateportal). Posts are designed to promote relevant research and products, explain climate phenomena, and promote TEK.

5. Summary and prospects

The primary objectives of the HCDP are to promote sharing and access to data and other information to facilitate research, improve awareness, foster collaboration, and promote the development of tools and resources that can help to build adaptive capacities in various sectors across the state. The HCDP is unique in many ways but also shares some of the attributes found in other data sharing platforms and portals (Teschke et al. 2022; Nguyen et al. 2019; Zhu et al. 2020; Allaway et al. 2019; Metzger et al. 2019). To ensure the HCDP meets specific user needs, an HCDP user group consisting of end users from several local, state, and federal agencies was established to provide feedback and to advise on future product development.

Ongoing and future work will focus on improving the cyberinfrastructure of the portal as well as the development of key initiatives to engage broad audiences with available data products and information. Several years of operation have so far highlighted the importance of continued efforts to both maintain and improve upon existing infrastructure. A proactive approach to maintaining networks such as this helps to minimize degradation and maintain a consistent quality of data and infrastructure (Kirchengast et al. 2014).

a. Future products and opportunities. From a product perspective, the HCDP is designed to accommodate new gridded surfaces as they become available. Gridded products that are currently in some stage of development include seasonal land cover, bimonthly normalized difference vegetation index (NDVI) without cloud contamination, daily rainfall and relative humidity, and hourly solar radiation and wind speed maps. Work is also underway to develop daily rainfall grids for the U.S. territories of Guam and American Sāmoa, and the cyberinfrastructure to host them, which is critical given the known climate data gaps in U.S. territories (e.g., Basile et al. 2024).

A number of decision support tools that leverage both historical and near-real-time gridded products are also in development. These include wildfire risk and warning tool, a drought forecasting tool for ranchers, and a tool to generate site-specific historic climate portfolios (e.g., Longman et al. 2022b). It is our hope that these products will be integrated into statewide early warning systems to help protect property and life.

Some federal agencies are also in the early stages of utilizing HCDP data to inform their own products and services. With the new creation of state climate divisions (Luo et al. 2024), NCEI is using HCDP rainfall and temperature grids to produce a monthly "State of the Climate" report, which until now was only available for the CONUS. The USDA Risk Management Agency (RMA) is using HCDP rainfall grids to develop an insurance product to ranchers to help protect against forage loss during drought.

In summary, we are optimistic that the HCDP will continue to serve the data needs of end users across a range of environmental and social disciplines. The establishment of a Hawai'i Mesonet with over 100 new climate stations installed over the next 2 years will be a great asset to the HCDP and the broader community as these high-quality station data will help to inform new datasets. The Hawai'i Mesonet project and other related projects built around

HCDP infrastructure will undoubtedly help to ensure the lasting vitality of this resource so that it will continue to serve a wide range of users including researchers, resource managers, city planners, teachers, students, civil society organizations, and the community at large for many years to come.

b. Usage statistics. The HCDP was officially launched to the public on 3 March 2022. Since that time ~45 000 unique users from 130 different countries have accessed the site over 100 000 times, and over 20 million files have been accessed as of 1 April 2024. The Hawai'i Moon Calendar page in the "Cultural Resources" section is the most visited page on the portal.

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Data availability statement. All data discussed in this paper are publicly available at https://www.hawaii.edu/climate-data-portal//. The source code of the back-end Tapis framework and HCDP web API services is available at https://github.com/tapis-project and https://github.com/HCDP/hcdp_api, and HCDP front end is available at https://github.com/HCDP/hcdp_application. HCDP data can be accessed for commercial use through an agreement with the University of Innovation and Commercialization (https://research.hawaii.edu/oic/).

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