ClimaTales: A Physicalization Story-Telling Tool for Climate Patterns

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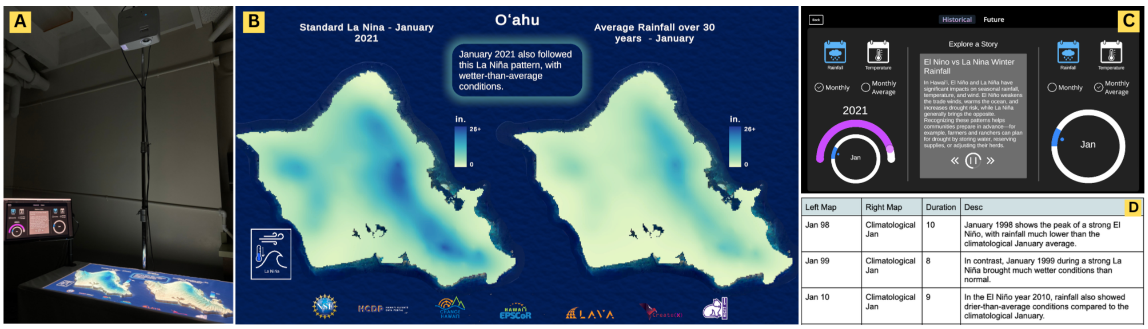

Fig. 1. ClimaTales' Storytelling Mode. Figure A shows the system's hardware. Figure B shows a snippet from a story being projected onto the table. Figure C shows the interface on the touchscreen mid-story. Figure D is an example of the storyboarding table that shows the structure of a script.

With the ubiquity of sensor networks and scientific advancements, large amounts of geospatial climate data are now publicly available. However, not everyone is able to interpret it. Data physicalization is a useful tool to provide context for geospatial data to audiences with diverse levels of domain knowledge. Data storytelling is used to make complex data more relatable. ClimaTales, the tool we present in this paper, leverages both data physicalization and data storytelling to promote self-exploration of climate data and help domain scientists author data narratives.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**.

Additional Key Words and Phrases: Physicalization, Data Narratives, Narrative Storytelling

ACM Reference Format:
Marissa Halim, Nurit Kirshenbaum, Keri M. Kodama, Ryan Longman, and Thomas Giambelluca. 2026. ClimaTales: A Physicalization Story-Telling Tool for Climate Patterns. In *International Conference on Pervasive Displays (PerDis '26), March 16–18, 2026, Munich, Germany*. ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3797993.3798027

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1 Introduction

In climate science, sensor networks are used to collect real-time environmental data such as temperature and precipitation. Platforms, like the Hawaii Climate Data Portal (HCDP) [8], allow the public to have easy access to the large database of climate data collected by the sensors as well as interpolated gridded data maps [9] derived from that data. To further disseminate the collected data, we propose ClimaTales, an interactive physicalization storytelling tool. The ClimaTales system is built off of prior research [12, 25] showcasing geospatial data projected onto 3D terrain models. This tool allows a wide range of users to interactively compare and contrast monthly geographical heat maps of Oahu's mean air temperature and mean precipitation values between 1990 and 2024 side-by-side as well as learn about anomalies in climate patterns through narrative stories written by researchers. It will also allow scientists to easily author stories about specific anomalies or time periods without having to program the software directly.

2 Related Works

2.1 Sensor Networks

Environmental sensor networks [14] are used to collect a wide range of data that domain experts use for monitoring and making predictions. As these sensors are deployed in different locations (both to gain insights from locations that experience different climate conditions and to increase the area that is covered by measured data) they inherently have geospatial significance. The amount of data collected is also quite intractable. Scientists are making great efforts to make these data available to the public - but availability is not enough, and efforts are now focusing on *accessibility*, making the data both available and easy to understand. Many of the current efforts are web-based [2, 15]. However, the ClimaTales tool is using a different approach, and together with the existing web-based portals it aims to appeal to a wider audience in cases like educational outreach or stakeholder meetings.

2.2 Physicalization

Data Physicalization [6, 11] refers to the capacity to express data through the physical properties of an object. There is a growing interest in this field [3, 22]. In this work, we focus on a Spatial Augmented Reality (SAR) based system [4]. These kinds of systems augment physical surfaces using projectors, as opposed to using phone views or head-mounted displays, allowing multiple users to share the same space. They have been prevalent in both entertainment [21] and educational [17] spaces. Projection onto physical terrain models, as initiated by Ishii's et al. *Illuminating Clay* [16], allows users to experience a sense of presence and connection [5] to the land they are learning about. It encourages users to directly interact with the 3D models (e.g., touching specific landmarks) to gain a better understanding of the relationship between data and geographical features [17]. Touching the 3D models acts as a cognitive aid that helps with future data retrieval [10, 19]. Such Physicalizations are both aesthetically pleasing to look at and better at engaging wide audiences [12], and therefore serve as an appropriate base for the development of ClimaTales.

2.3 Narrative Data Visualization

As mentioned above, even if the public has avenues to retrieve scientific data, there is no confidence that they can understand it and draw insights based on it. Most people do not have domain knowledge and would not know how to unravel the vast amounts of data.

In data-driven journalism, where the main purpose is to communicate the data in an understandable way, Lorenz [13] discusses the need to translate the data into a story so it becomes information in a context that the public can understand.

Segel and Heer's research on narrative visualization explains the spectrum of *author-driven* and *reader-driven* approaches to developing data stories [23]. An author-driven approach will have linearity, messaging, and little to no interactivity. On the other hand, a reader-driven approach has no messaging and will allow readers to explore and interact with data however they want. The Martini Glass Structure detailed by Segel and Heer presents a balance between the author-driven and reader-driven approaches, where readers are first guided by the author and then freed to explore the data however they see fit. We adopt a similar, though reversed, approach in our work.

3 System

3.1 Hardware and Software

ClimaTales is an interactive tool that allows users to learn about climate data projected onto 3D terrain models through free exploration and narrative storytelling. Using a similar system as the ProjecTable [12, 25], the ClimaTales tool is made up of the driving computer, a ViewSonic touchscreen monitor, Optoma projector, and two 3D-printed terrain models on top of a table (see Figure A in Fig. 1). The touchscreen monitor is mounted onto a rig that is attached to the left side of the table at around chest-level. The projector is mounted on a stand that suspends it around 5.5 feet above the table. The 3D models are about 20 inches by 14 inches — large enough to clearly display data layers while also small enough to fit side by side, overall supporting the goal of comparing data in topographical context.

The software for this tool was built using Unity 2022.3.11f1 [26] and uses two canvases: one for the touchscreen (see Figure C in Fig. 1) that includes all of the interaction widgets, and one to be projected on the table and terrain models (see Figure B in Fig. 1) that includes the maps, labels, scales, and other data layers.

As part of the data retrieval process, we first download .tif files with the desired data directly from HCDP and process them using QGIS [18], a free and open-source Geographic Information System (GIS) software. We use Python scripts to organize and rename the files as well as to calculate bounds for the color scales. We use Adobe Photoshop [1] to refine graphics such as the base maps and color scales. All of these resources are brought into the Unity project, where the state of the system is managed by scripts that programmatically determine which maps, labels, and scales to project onto the table. In the future, we hope to directly connect the HCDP platform with ClimaTales to reduce the time needed for data retrieval and processing, allowing greater efficiency and a wider variety of data and stories.

3.2 Interactivity

The system includes two modes: Interactive mode and Storytelling mode. In Interactive mode, users can explore *historical* and *future prediction* data. Historical data UI elements include toggle buttons for the data type (temperature or rainfall), toggle to switch between averages over the last 30 years or monthly/yearly data, sliders for controlling the years (for yearly data) and months, and a tab button to switch to future prediction data. Future prediction data UI elements include buttons for 10 different scenarios based on data type, time data (Present time vs. Late Century 2070-2099), downscaling method, scenario type (Best-case vs. Worst-case), and a tab button to switch back to historical data. The UI is doubled: one set of widgets on the right to control projection on the right model and one set of widgets on the left to control projection on the left model.

In the Storytelling mode, ClimaTales autoplays for the viewers a science story, currently focusing on the historical data layers. When users select a story, they are presented with a structured and scripted sequence of data layers on both models accompanied by an appropriate narration written by a scientist. The Stories player UI on the touchscreen is set between the exploratory UIs of the Interactive mode, allowing an immediate switch from one mode to the other.

The player includes a play/pause button, skip forward/go backward buttons, and can be set to autoplay after a set time of inactivity on the system has elapsed.

The terrain models are meant to encourage tangible interaction and collaboration [11, 24]. In our experience while demoing ClimaTales, users point and refer to the terrain models when communicating their observations. They point out landmarks they are familiar with, more often than not their home or work locations, which helps them draw connections between place and data. We believe the tangible aspect of the models and their tactile potential can be instrumental for engagement and understanding of the underlying science, but this requires further study.

4 Use Case

We present here an example story that uses the ClimaTales Storytelling mode to inform the general public about the El Niño–Southern Oscillation (ENSO) climate phenomena. This story first guides the viewer through expected El Niño and La Niña patterns — El Niño years are expected to be drier than the average while La Niña years are expected to be wetter. It then shares some examples where these patterns were broken, and ends with the caution that such unexpected rainfall patterns can cause risks, such as agricultural and financial damage, and should be carefully monitored. This story was written in collaboration with domain scientists. The comparative nature of ClimaTales allows this story to easily show examples of rainfall for a specific year and month on one side of the display while the average rainfall is shown on the other. The result is a 2 minute narrated experience.

Taking inspiration from animation storyboards, we have developed the ClimaTales software to allow users to build a story script (see Figure D in Fig. 1) made up of “pages” in a JSON file. Every page includes a description (the accompanying text), layers to be shown on the left and right sides of the display, and the duration of the page. To make the story experience more immersive and mitigate the need to constantly look between the touchscreen monitor and the projections on the table, we use ElevenLabs [7] to generate the audio of each page’s descriptions, so that users have the option to listen, read, or both when a story plays. The audio clips are brought into the Unity project and connected to the script that drives the Storytelling mode.

ClimaTales is ideal for educational and public spaces such as museums and conferences, where it can reach a wide range of people. It is also a strong tool to be used for decision making with stakeholders such as farmers and fire marshals. Its advantage is that the system is modular and can be easily taken on the go.

5 Discussions and Future Work

Narrative Visualization. Our system offers an immersive way for users without domain knowledge in climatology to interact with the data and allows researchers to communicate their findings in a compelling format. Existing platforms for sensor network data make large amounts of invaluable data available to the public, but rely on the users’ motivation to engage and understand that data. This is not always the case with wider audiences, leaving data available but unused.

ClimaTales uses narrative visualization to bridge that gap. Using prior research from Segel and Heer [23], ClimaTales employs a reverse Martini Glass Structure, where users can first explore the data and draw their own conclusions in Interactive mode, but they can also be guided by a story that contains domain knowledge in Storytelling mode. This tool provides a balance between an author-driven and reader-driven approach to data narratives: the stories in ClimaTales are curated by scientists and have a clear story progression and takeaway message, while the interactive mode allows users to freely explore the data at their own pace.

System Adjustments. This project implemented some system changes compared to past projects such as ProjecTable [12]. In ClimaTales, instead of using physical pucks for interacting with the projected data, we used a touchscreen interface, which is both a cheaper, off-the-shelf solution, as well as commonly used in everyday life. By using a technology that most people are comfortable with, users can focus more energy on exploring the data, drawing conclusions, and having conversations about their findings. In addition, instead of using a large, central 3D model, this system uses two smaller 3D terrain models which facilitate compare-and-contrast tasks. This is especially useful for the time-series data our system contains.

Limitations and Future work. The current version of our system focuses on Oahu's rainfall and mean temperature, though the web-based HCDP has a much wider range of data to be explored and also has some near real-time data products. We limited our focus to historical data from 1990 to 2024 to avoid system bloat. However, due to this choice, there is a limitation on user exploration and story authoring. Future work on this project could include a direct connection to the HCDP so that users can explore historical data, real-time data, and future prediction data. Such a connection would also reduce the preprocessing time for data layers as they may be fetched directly through an API.

To determine if ClimaTales is a successful tool for communicating climate science to people without any domain knowledge, we can conduct an empirical study like the one Rodriquez et al. [20] suggests. In this study, participants would be observed to learn if they are invested in a data story or distracted by the other interactive features of the tool. In the study, we will use the story from our use case and then determine if the narrative visualization aspect of ClimaTales helped, hindered, or did nothing to help users learn about ENSO.

Acknowledgments

This work was enabled in part by funding from the National Science Foundation awards: 2139133, 2201428, 2232862, 2004014, 2003800, 2003387, 2117975, 2138259, 2138286, 2138307, 2137603, and 2138296.

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