Local Climate Data Stories: Data-driven Storytelling to Communicate Effects and Mitigation of Climate Change in a Local Context

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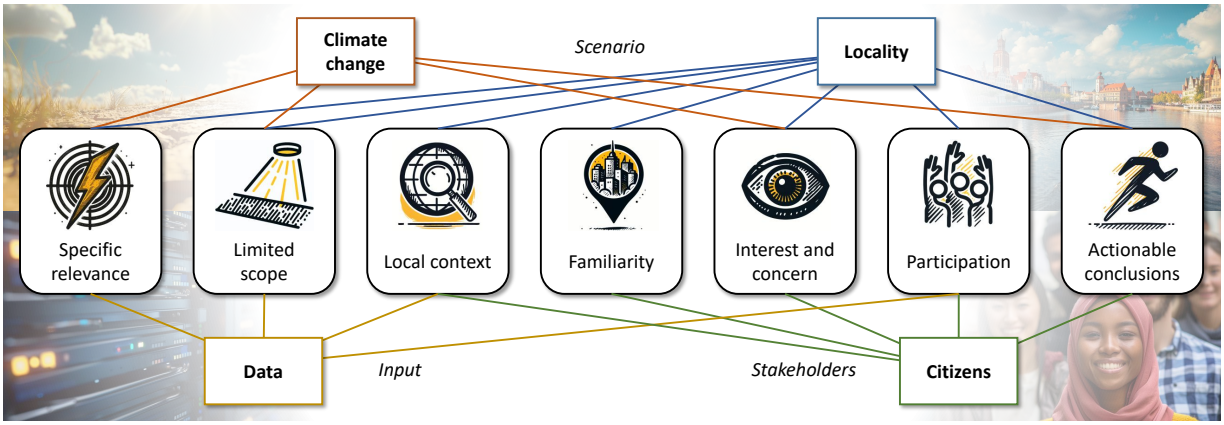

Figure 1: Characteristics of the local climate data stories (center) and their main relationships to key concepts (top/bottom).

Abstract

Presenting the effects of and effective countermeasures for climate change is a significant challenge in science communication. Data-driven storytelling and narrative visualization can be part of the solution. However, the communication is limited when restricted to global or cross-regional scales, as climate effects are particular to the location and adaptions need to be local. In this work, we focus on data-driven storytelling that communicates local impacts of climate change. We analyze the adoption of data-driven storytelling by local news media in addressing climate-related topics. Further, we investigate the specific characteristics of the local scenario and present three application examples to showcase potential local data-driven stories. Since these examples are rooted in university teaching, we also discuss educational aspects. Finally, we summarize the interdisciplinary research challenges and opportunities for application associated with data-driven storytelling in a local context.

Index Terms: Data-driven storytelling, narrative visualization, local data, climate change.

1 Introduction

Although climate change is a global phenomenon, it also must be addressed and understood at the local level. Its effects may vary widely in different local contexts [12], ranging from desertification because of a dryer climate to flooding due to rising sea levels and extreme rainfalls, extinction of endemic species, etc. Global temperature curves, while alarming, often seem abstract and may not resonate on a personal level, nor do they consider any local contexts. Demonstrating the effects of climate change on a local scale makes the problem more tangible and invites for community engagement [34], for example, regarding local flooding [32, 28] or changing agricultural land-use [8]. This approach may not only enhance understanding but could also help better cope by contributing to local efforts to combat climate change or adapt to the changing circumstances. Hence, communicating local effects of climate change and local mitigation strategies should be a key element in any promising adaption strategy to fight catastrophic local impacts of global warming. Visual imagery, including data visualizations, are powerful tools to shape the perception of climate change [26], and versatile storytelling approaches can be applied [23].

In this work, we take a local perspective—considering local contexts and their distinctiveness [7], but also the implications of the restricted geographic scope. We discuss the use of data-driven storytelling and narrative visualization methods for communicating local data (Section 2). Investigating stories from local newspapers, we provide preliminary evidence that related examples already exist, but do not yet use the potential offered by data-driven storytelling (Section 3). We explore special characteristics of the local scenario and opportunities that are particularly relevant to the local context (Section 4); Figure 1 lists the identified characteristics and connects them with relevant concepts of the studied local perspective. Three examples of local climate data stories that were developed as student projects at our university illustrate a more advanced use of data-driven storytelling methods, including interactive visualization, and exemplify the discussion of local characteristics (Section 5). Stemming from teaching projects, the examples also showcase the potential of leveraging such local data stories in an educational context (Section 6). Finally, we outline challenges for future, interdisciplinary research to support the effective communication of local climate data (Section 7).

Hence, while not contributing new data-driven storytelling solutions, the paper provides a multi-faceted discussion of a relevant application scenario of such stories. It advocates that underexplored *local* dimensions of data stories should be investigated in more detail. Although the examples discussed mostly relate to temperature and precipitation data, we consider data relevant for climate

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Table 1: The analyzed articles listed with publication date and newspaper, characterized by topic, used data, and visualization.

ID	Title	Date (2023)	Newsp.	Topics	Data	Vis.
A1	*Erst Hitze, dann Regen zur Ernte – Bauern im Klimastress* (*First heat, then rain for the harvest – farmers under climate stress*)	Aug. 5/6	LVZ	Farming	Precipitation	Bar
A2	*'Jeder Tropfen zählt'* (*'Every drop counts'*)	Aug. 9	LVZ	Precipitation	General data	–
A3	*Apfelernte in Sachsen läuft – Obstbauern mit Zukunftsängsten* (*Apple harvest ongoing in Saxony – fruit growers with fears for the future*)	Sep. 16/17	LVZ	Farming	General data	–
A4	*Hamburg wird immer heißer* (*Hamburg is getting hotter*)	Sep. 29	HA	Climate conference	Temperature	–
A5	*Trockenheit und Starkregen* (*Drought and heavy rain*)	Oct. 20	LVZ	Urban resilience	Qualitative	–
A6	*Wetter in Leipzig: Wie warm und nass war der Oktober im Langzeitvergleich?* (*Weather in Leipzig: How warm and wet was October in a long-term comparison?*)	Nov. 2	LVZ	Weather trends	Temperature, precipitation	–
A7	*'Das Klimasystem fliegt uns gerade um die Ohren'* (*'The climate system is blowing up in our faces'*)	Nov. 7	HA	Heat	Temperature	–
A8	*Der Schreck vor dem Klimawandel bleibt aus* (*The scare of climate change does not occur*)	Dec. 16	LVZ	Weather trends	General data	–

data stories as being much more versatile, for instance, potentially also covering land use and agricultural statistics, biodiversity and forestation, urban mobility and buildings. All these domains are affected by climate change and need to adapt on a local level.

2 Background and Related Work

Data-driven storytelling and narrative visualization [10, 30] has become an established means of data communication. While examples from leading national journalistic publishers are most well known, also non-profit organizations, educational institutions, government agencies, and local news platforms can leverage such data stories and adapt them to the local level. The formats of data stories are not limited to scroll stories (*scrollytelling* [31]), but also include other magazine-like formats, slideshows, infographics, and comic strips [30], or typically combined with audio narration, can be presented as animated videos [19] or in virtual reality [17]. Numerous examples demonstrate that geographic data can be well communicated through such data stories [16, 19, 20]. Some data stories relate to climate data, for instance, 46 among the 130 spatio-temporal stories studied by Mayer et al. [20]. While some of such examples might have a local perspective, we are not aware that the local perspective and context has received special attention in the data-driven storytelling literature.

Communication-oriented visualization of climate data can be considered on multiple scales, ranging from global and continental scales to local views [27]. On the local level, the visualizations may focus on realistic depictions of places and may be able to draw on one's own experiences. Rendered images of specific places can help illustrate certain scenarios and show effects, for instance, of flooding, snow coverage, or land use [32, 34, 33]; but such images have also been criticized for being overly simplified and subjective [24]. However, more data-driven approaches also exist and potentially give more realistic and nuanced impressions. For homeowners, *VisAdapt* [13] shows visualizations of predicted climate risks for a selected house and location. *HORA 3D* [28] visualizes flood scenarios for specific local contexts in an advanced 3D simulation. We hence see local scenarios considered in climate data communication embedded in different context, but not directly discussing it from a data-driven storytelling perspective.

3 Climate-related Stories in Local Journalism

To provide an intial point of reference, we first explore journalistic examples of local data-driven reporting of climate-related topics. We conducted a search on all articles published from August to December 2023 by two local, daily newspapers from Germany: *Hamburger Abendblatt* (HA), Hamburg and *Leipziger Volkszeitung* (LVZ), Leipzig. We accessed the *wiso* database, containing all articles of the print-layout versions of these newspapers. For (sub)title search, we used *Klima UND Wetter* (*climate AND weather*). We decided for this to ensure the local relevance of the articles, as the weather is an indicator of the local impact of climate change, as well as to limit the results and allow for a qualitative analysis. The search resulted in twelve articles (HA: 5; LVZ: 7). Four articles were excluded from the analysis because they were either advertising local events and projects (two cases in HA), non-local (one case in HA) or not data-driven (one case in LVZ). All included eight articles are listed in Table 1 and numbered A1–A8. We analyzed them regarding the covered topic, as well as data and visualization used. Looking at the topics of the eight articles, we see that the extreme weather and the impact of climate change on local farmers are important topics. Five articles report on local extreme weather events, focusing on extreme heat (A4, A7), drought and rain (A2, A5), and comparing last month's weather with that of previous years (A6). In two articles, they interview farmers who report on their harvest and the influence of the weather on it (A1, A3). The data described in the articles span from temperature and precipitation to more general data. In many articles, temperature data is used as information that readers can relate to and which is of significance to them in their everyday lives (A4, A6, A7). Similarly, this applies to the two articles that deal with precipitation data (A1, A6). Subsumed as *general data* are briefly mentioned data, providing context by mentioning years of drought and average temperatures (A2), comparing the size of cultivation areas (A3), or listing temperatures, disasters, and events that have happened lately due to climate change (A8). Article A5 employs a different approach, as it does not provide specific numbers but presents problems caused by the local weather and possible solutions to make the city more resilient.

To our surprise, almost none of the articles contained any visualizations, but just stated the raw data in text. Especially in paragraphs where temperature is compared over time or with other regions, we suggest an additional visualization would help to make the argument clearer (A4, A6, A7). The articles either did not include any image or figure (A4), used a generic photograph to illustrate the topic (A7, A3, A6, A8), or photographs of the people and events discussed (A2, A5). Only one article (A1) contains a bar chart created by the newspaper to visualize the current precipitation per month in the city compared to the 50-years average. The rather simple visualization appears to help the reader to understand the data and is considered easy to read.

Although these examples only shed partial light on local journalistic practices, we can conclude with two preliminary findings. First, while climate change is a dominant topic in public debate, local newspaper might only publish relatively few truely data-driven articles related to climate and weather referring to local data (none of the articles included an in-depth data analysis). Second, local journalists seem to choose illustrating, generic photographs rather than data visualizations, despite the hypothesized visualizations' power to make data-related articles more accessible. We hence see that the general interest in climate-related topics might not yet be matched on the local level through respective data stories and a maybe largely unused potential for narrative visualization methods. Still, further investigation is necessary, specifically, to study more sources of local news stories and a broader range of climate-related topics. Interviews with the authors—the local journalist—could give more profound insights and help understand the journalistic decisions for or against certain forms of presentation and communication. Additionally, a quantitative approach, trying to measure the attributed relevance of the topic by authors as well as readers, would provide a complementing view.

4 Characteristics of the Local Scenario

Considering a broader perspective, we discuss how storytelling with local data differs from storytelling with non-local data, and what opportunities localization offers regarding climate data. To this end, we formulate the following local characteristics and reference them throughout the paper using illustrating icon images (generated through *DALL·E*). Figure 1 (illustrating background images genered through *Midjourney*) further connects the characteristics to different concepts that form the main dimensions of local climate data stories, namely *climate change* and *locality* specifying the scenario, *data* providing the main input, and *citizens* (broadly defined, also including local institutions and companies) as the stakeholders involved in producing and consuming the stories.

Specific Relevance Depending on its geographic location and features, the *local* effects of *climate change* on a city or region might be quite different [12]. A coastal city might be impacted by rising sea levels, while an inland city would be affected by rising temperatures, changes in precipitation, and extreme weather conditions. Because of these changes in the local climate, vegetation might need to adapt drastically, but the specific impact will vary in different areas. Moreover, the local geography (topography of a place, lack of green spaces, the density of the development) create special conditions for a locally sensitive handling of the effects of climate change. Therefore, potential data story topics that are relevant to a specific place can be quite different; for instance, the fact sheets provided by the *Intergovernmental Panel on Climate Change* (IPCC) [11] can be starting points to identify the topics of locally high specific relevance.

Limited Scope Obviously, the *local* scenario substantially restricts the *data* that can be used for storytelling. Moreover, data availability is not distributed evenly across locations (e.g., restricted historic weather data in sub-Saharan Africa [14]). On the one hand, poorer data availability and potentially lower data quality on the local level is a critical issue. Certain stories might not be feasible to tell because the data is not at all available, while in other cases too few data points do not reliably draw a clear picture. On the other hand, the smaller scope and scale is an advantage. By chance, some data that would be difficult to acquire on non-local scales might be available in the specific local area. Moreover, if certain contextual information is missing, it might even be possible to manually extend the data or record it with one's own equipment, for example, taking additional pictures on-site or manually classifying different regions and quarters of the city based on their characteristics.

Local Context In many applications, *data* needs to be contextualized or interpreted regarding the *local* environment in which it was recorded. For example, depending on the dominant use of a quarter, urban heat islands would need to be judged and addressed with different priorities and means. The main forms of mobility and locations of main touristic attractions likely impact mitigation strategies (e.g., cultural heritage sites might both restrict options for transformation, but possibly also offer access to additional funding schemes). On the local level, also certain assumptions can be made more easily and should be considered, such as on acceptance levels of *citizens* for different modes of transport or on habits and traditions with certain environmental impact (e.g., gardening traditions in the city of Bamberg [25]). Developing a story that spans across multiple cities and regions often makes it difficult to consider such local context, rendering the story generic or drawing misaligned conclusions.

Familiarity Within a *local* context, we can assume that most readers of the story, as *citizens*, will be familiar with the local geography, such as the city layout, its various quarters, rivers, and surrounding landscape, because these constitute large portions of the everyday action spaces of the inhabitants. This familiarity essentially provides us with an audience of experts who have extensive experience living in the respective region or city. Therefore, we can delve deeper into the data analysis and build on this background knowledge. But the citizens' sense of place and belonging might reach beyond only a technical understanding of place, and includes emotional and social dimensions that can be addressed as well in data stories. Some familiarity and sense of place can be assumed for the whole city or region, but might intensify on a *hyperlocal* level (i.e., quarter or village, block, and street levels).

Interest and Concern While not all *citizens* are immediately concerned about the general effects of *climate change*, for example, seeing one's own home flooded in simulated imagery will likely raise interests [32, 28]. Typically, individuals are deeply interested in their immediate *local* surroundings, especially if there is a direct impact on their daily lives. This heightened and shared concern for their direct environment creates a momentum of engagement that might be absent on a more global scale, or might only resonate with a specific segment of a general audience. Whereas such raised affectedness is certainly a good starting point for data-driven storytelling, it potentially comes with increased likelihoods for heated debates and dangers to fuel such non-constructive discourse.

Participation On the *local* level, various actors and institutions (generally, *citizens*) may be interested in participating, for instance, in *data* collection or analysis. Examples include various forms of *volunteered geographic information* [5] or *citizen science* projects like crowdsensing initiatives [1] and other efforts to collect local data. Such data can be included and discussed with the providers of the data to learn about specifics and generate ideas for communicating the data. Local experts are readily available and often willing to contribute, albeit typically on a voluntary basis with limited resources. Positive side effects of participatory data analysis processes can be gained data literacy [29] and sense of ownership. Generally, the small scale makes it easier to reach a critical mass of data and contributions. Moreover, the accessible visual reporting of the data can be a vehicle for local citizen participation in decision making [34]. Still, representativeness of such participation remains an issue, as not all social groups might be equally willing or able to contribute.

Actionable Conclusions On a global scale, the conclusions of a data-driven story might be difficult to make actionable for the individual. While general advice can be given, such as consuming less meat or tak-

ing fewer flights, individuals might have the impression they cannot impact global problems. On the *local* level, however, the impact can be much more tangible. Individual *citizens* can join local initiatives to mitigate *climate change*, achieving a more realistic and direct influence on adapting the local situation. Therefore, conclusions from data analysis can be translated more easily into specific, actionable steps for individuals.

5 Application Examples

To showcase the potential of data-driven storytelling for climate change data in a local context, we present three interactive examples developed by students (names provided in alphabetic order) of the University of Bamberg, localized to the city of Bamberg, Germany, and the state of Bavaria, respectively. The presented examples include two web-based scroll stories and an interactive animation, demonstrating that different genres of narrative visualization [30] can be effectively utilized for such storytelling. All three examples focus on the local effects of temperature and rainfall—topics with high *specific relevance* in the continental climate of Bavaria, Germany. However, they employ diverse data sources, including crowd-sensed weather data, satellite images, and climate predictions. These varied approaches highlight the adaptability and creative potential of narrative visualization in addressing local environmental issues. Figure 2 provides an overview of the stories through sequences of selected cutouts. The examples, given their local audience, are written in German, but translations of the texts are provided in the supplemental materials along with either further screenshots or video demonstrations of the stories. Although being involved in the supervision of the three projects, we do not claim ownership of the solutions, but fully attribute them to the student authors of each of the solutions. The projects form the subjects of the following discussion, but we did not alter the projects in any way to better align with the content of this work, and do not consider them as models ideally adressing the discussed characteristics.

5.1 Urban Microclimate

The first example presented in Figure 2(I) is a web-based scroll story that explores differences in urban microclimates through crowd-sourced measurement, as well as introduces the concept of the *sponge city*, that is, a city that, by aggregating water, has a cooling effect and does not heat up as much. Referencing the concept, the story is titled in German, *"Schwamm drauf,"* which translates to *"Put a Sponge on It"* (a variation of the German proverb *"Schwamm drüber,"* which translates to *"forget about it"*). The story was authored by **Florian Aschinger** and **Pascal Löffler** as part of the Master-level project course *Bamberg Data Stories* in Summer 2023. It is publicly available at `https://schwammdrauf.wolperlab.de/`.

Story After a brief introduction (I.a), the story presents the official weather station of the *Deutscher Wetterdienst* (DWD, the national weather forecast service), located outside of Bamberg (I.b). It contrasts this with another weather station within the city, which, although not used for official weather reporting, provides a more urban perspective. The narrative then shifts to a crowd-sensing project initiated in 2014 and expanding since, comprising, when creating the story, 62 sensors distributed across various locations within the city to record microclimate data (I.c). The story further delves into the identification of different local climate zones [38], which are mapped to specific areas of Bamberg (I.d). The story analyzes data collected over one year, highlighting the differences between the local climate zones and the official measurements taken by the *Deutscher Wetterdienst* (I.e). It reveals that temperatures within the city are consistently higher than those officially reported, with an average increase of up to three degrees Celsius during summer. The narrative then examines the phenomenon of hot summer nights, illustrating how temperatures evolve during these periods (I.f). Finally, the story introduces the concept of the sponge city as a countermeasure to urban heat effects. The narrative concludes with an example of green roofs of bus stops, presenting them as a viable and positive solution for future urban planning (I.g).

Visualization and Interaction At the heart of the story is a dynamic map representation of the city of Bamberg, which remains constantly visible in the main part of the story and does not scroll with the text (I.b–g). The main interaction is scrolling, which steers the animation. As new text blocks are introduced, each relating to specific locations within the city, the map animates to center on these locations (e.g., I.b, I.g). As the narrative progresses, the different sensors are visualized on the map according to their installation dates (I.c). Local climate zones are then demarcated and color-coded on the map based on deviations from the official measurements (I.e). The map comes along with line charts that provide a timeline representation of the temperature data (I.e). This encoding strategy is similarly employed to depict temperature variations during a hot summer night (I.f). On different occasions, the user can explore details—presented through tooltip dialogs—by hovering specific data points (e.g., I.b) or regions (e.g., I.e).

Local Characteristics The story adopts a distinctly local perspective, focusing not just on a city, but also on the circumstances—namely, the official temperature measurements being conducted outside the city limits (*specific relevance*, *local context*). The availability of alternative measurements is a crucial foundation of the story (*limited scope*). This external measurement contrasts with the urban microclimate, which has a more direct impact on the city's residents—personally experienced temperature might be systematically higher (*interest and concern*). The data for this project was collected through a crowdsourcing campaign orchestrated by a local community association, the *Bürgerverein Bamberg-Mitte*. Additionally, the development of the story was advised by members of the *Bürgerverein* and an expert in micrometeorology, ensuring the narrative to be both locally relevant and scientifically grounded. This collaboration highlights the value of community involvement (*participation*). Missing fine-grained data on local climate zones was balanced by manually defining such regions (*limited scope*). Finally, *actionable conclusions* are presented through existing initial examples (i.e., green roofs).

5.2 Heat and Vegetation

The second example, titled *"Hitze"* (German for *heat*) and shown in Figure 2(II), revolves around a similar theme, but focuses on heat situations and their effects on vegetation health. It shifts the focus away from the dense urban core to the city's parks and surrounding green areas. It is also implemented as a scroll story with map-based representations and temporal line charts. It was authored by **Jakob Högerl** and **Tobias Lierheimer**, also as part of the *Bamberg Data Stories* Master-level project course in Summer 2023.

Story After a brief introduction, which includes images showcasing dry conditions in park areas of Bamberg (II.a–b), the story explains how vegetation health can be measured through specialized satellite data. Through this, the health and density of vegetation within different areas of the city can be estimated and shown on a map contrasting different years (II.c). The story then guides through specific relevant aspects and examples (II.d–e). In the second part of the story, the focus turns to temperature curves. This section illustrates the historical temperature data (II.f) and incorporates predictions for future climate conditions (II.g), before finally concluding the story (II.h).

Visualization and Interaction Similar to the first example, the story employs a map-based representation and line graphics within a scroll story format. In contrast, however, the map leverages data derived from satellite imagery provided by the European

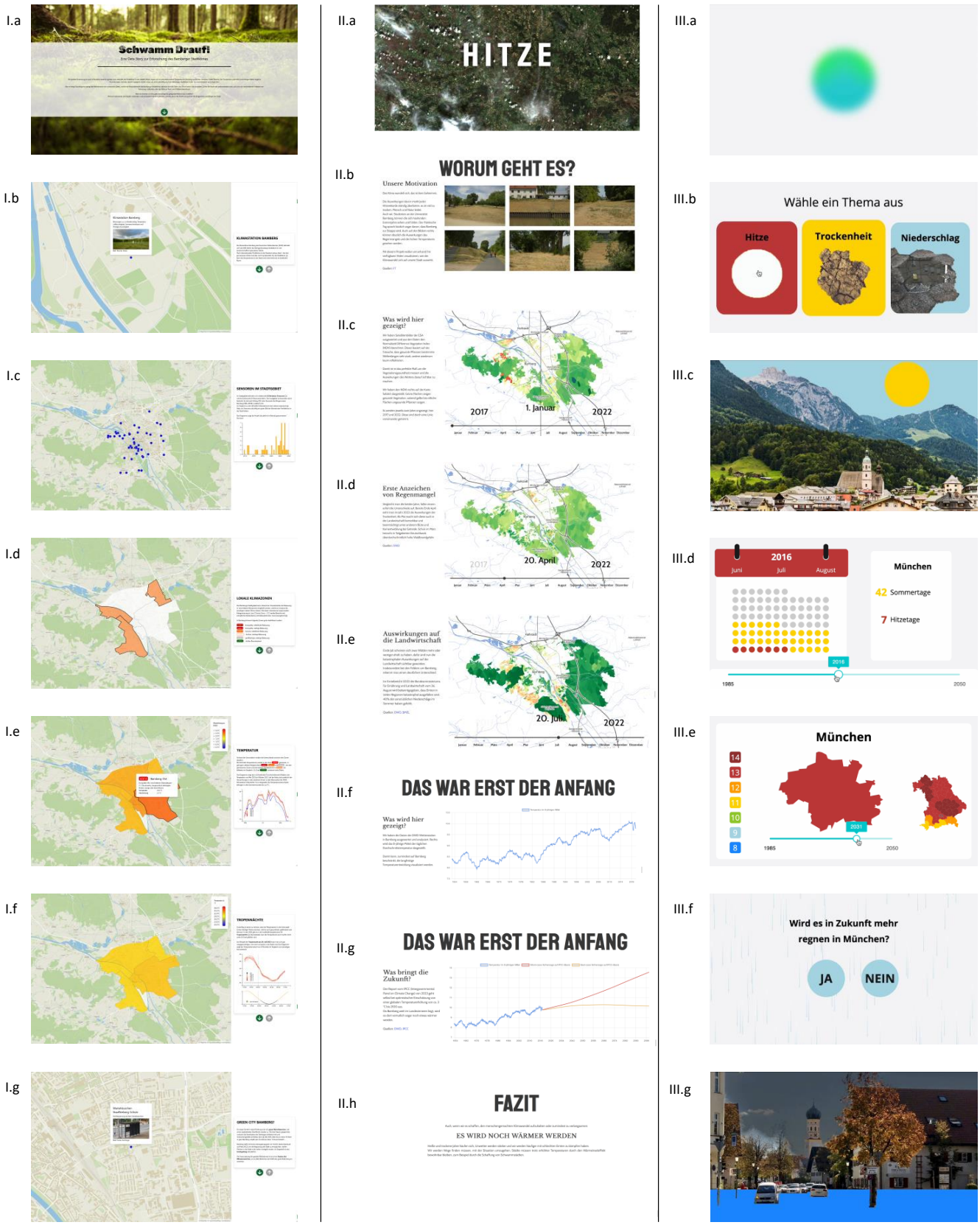

Figure 2: Excerpts of the three data stories that serve as application examples: (I) scroll story on urban microclimate, (II) scroll story on heat and vegetation, (III) interactive animation on climate prediction; a more detailed documentation is part of the supplemental material.

Space Agency (ESA), augmented by data by the *Deutscher Wetterdienst*. Specifically, it color-encodes the *Normalized Difference Vegetation Index* (NDVI) extracted from satellite data, which indicates the health and density of vegetation. In the first main part of the story (II.c–e), the focus is on the map, providing visual data about vegetation health and spatial distribution across the city area (i.e., also including surrounding fields and forest areas). In contrast, the second part (II.f–g) displays line charts that track temperature trends over time, without integrating map references. The story enhances user engagement by enabling interactive exploration of the data. Users can select specific years or compare multiple years side-by-side using a slider-based comparison tool on the map (II.c).

Local Characteristics The data adopts information that is available on a global level and tailors it for exploration within a *local context* . A crucial aspect of this adaptation is the mapping of the global data to specifically interpretable areas of the city's vegetation. This localized data was manually extracted and refined (exploiting the *limited scope*), with particular attention to larger forest areas that needed to be subdivided by tessellation for meaningful coloring-coding at reasonable scales. Illustrating images of well-known park areas with dry vegetation build on *familiarity* to raise *interest and concern* .

5.3 Climate Prediction

The third story, as showcased in Figure 2(III), is an interactive (untitled) animation that, similar to a video, displays predefined sequences accompanied by narrated audio. However, it also allows the user to make interactive decisions and includes interactive elements such as sliders. The topic revolves around extreme weather situations and predictions of their future likelihood in a specific local region. The story was developed by **Marco Lettner** as part of his Master thesis, which he completed in December 2023. The thesis was supported through a scholarship by *Media Lab Bayern*.

Story First, the user provides their name (for personally addressing the user) and selects a region or city in the state of Bavaria; then, the animation begins to play (III.a). After a brief introduction, the story offers a selection of three sections (III.b)—*heat*, *drought*, and *precipitation* are available topics. Once a topic is chosen, the story delves into the details of that particular subject, but later introduces the other remaining sections as well. For each section, the story first explains the situation through an animation with audio comment (e.g., III.c, III.g), partly connected with interactive quizzes (III.f). Then, it allows users to explore the predicted data for the selected region (e.g., III.d–e). After a topic is concluded, the story transitions to the next section.

Visualization and Interaction The story is based on prediction data officially published by the respective federal state ministry of the state of Bavaria (*Bayerisches Landesamt für Umwelt*). The animated presentation leverages different means to visualize frequencies and quantities (e.g., III.d–e). While the visualizations and interactions are simple and maintained consistently, they are themed according to the respective topic and are tightly integrated into the animation. For instance, in the heat scenario, the sun depicted in the previous scene transitions into an element of the visualization in the next scene (from III.c to III.d). Additionally, soundscaping (e.g., rainfall sounds in III.f–g) is employed to provide context for the topic and story. The interactions involve sliders and selections, such as selecting a year for prediction (III.d–e) or making guesses about future developments (III.f). The textual narration adapts to user selections and the specific region, and is generated on-the-fly through a text-to-speech service.

Local Characteristics While being tailored for the state of Bavaria (Germany) already provides some localization, the main customization occurs through user selection of a specific region or city. Following this selection, the data for the selected region is used (*limited scope*). Additionally, the theming of certain parts of the animation changes to reflect the respective landscape of the region, such as depicting higher mountains in regions of the Alps. Similar to the previous example, this approach contributes to a feeling of *familiarity* and, here reinforced by addressing the user by individual name, potentially enhances engagement by raising *interest and concern* about the user's local environment.

6 Educational Perspectives

The three discussed stories were created as projects in the context of teaching data-driven storytelling. In this paper, the thematically similar stories allow us to investigate alternative solutions for related local settings, but we also gained relevant teaching experience through supervising the projects. We reflect on our experience and discuss using topics related to climate change on a local level.

Benefits As described for a high-school context already, climate-related data-driven storytelling projects offer versatile teaching opportunities—*"participation in coding, data visualization, storytelling, and scientific reasoning simultaneously and in personally meaningful ways"* [29]. We observe that project-based authoring such stories, to some extent, addresses challenges and opportunities described for visualization teaching in a recent call to action [2]. Requiring and profiting from a mix of different technical expertise and knowledge (data analysis, programming, visualization, local knowledge, climate change, etc.), such projects leverage and embrace the diverse background of learners within a team [2, PPL2, PPL3, O1]. They clearly connect specific visualization skills with more general skills such as *"problem solving, critical thinking, creativity, collaboration, group work, debate and consensus-finding, project pitching, storytelling, visual design, communication, analytic thinking"* [2, MTH2]. Also from a teaching perspective, the projects profit from characteristics of the local scenario and the focus on climate through, for instance, the *limited scope* making the data handling more manageable, *familiarity* providing a solid local knowledge background, and raised *interest and concern* motivating students to actively contribute.

Challenges and Risks Within a group project, learners may focus on tasks they are good at already, only seeking limited opportunities to learn something new [2, MTV2]. We have observed such cases in some projects (not in those described above) and counterbalance by requiring everybody to contribute to the core implementation of the story. Fair assessment of individual contributions is a related challenge [2, GA2]. To address this, we define a clear visualization question at the beginning of our data-driven storytelling projects (e.g., a specific presentation format using certain interactions), which forms the basis for evaluation, while secondary contributions (e.g., storytelling, design) are treated as bonus. For group work, we make sure to receive individual project reports reflecting the learning experience, as well as conduct short individual interviews. While it sounds appealing and rewarding to also *publish* the student-created data stories, this should not be done unreflected. Developing a first prototype might be feasible in a course; however, it might not yet be sufficiently tested and support different devices. Moreover, questions of copyright needs to be considered, as well as legal questions of publishing (e.g., responsibility for the content). Moreover, the content of the story needs to be quality assured, potentially involving external experts. Finally, exposing learners—who might require a protected environment—to public debates can be an ethical concern. We, hence, recommend managing the expectations clearly, that is, that the stories do not need to get published and that it is challenging to do so. As teachers, we should not pressure any student-authored story into publication and separate publication opportunities from the assessment of the work. Nevertheless, we want to encourage students to contribute their knowledge to public debate and thus actively promote the transfer of university knowledge into civic society.

7 Research Challenges and Opportunities

Local data stories represent a relatively under-researched area with promising applications, such as in communicating data related to climate change. We hence aim to explore specific research challenges and opportunities for practical application that such local stories present. While climate change serves as a pertinent example, the research challenges and opportunities identified are likely applicable to other local interest topics as well. Given data stories' connections from data science and digital media to journalism, communication sciences, sociology, geography, and other fields, addressing these points may necessitate interdisciplinary collaboration. Examples and related literature is referenced where available, but often only describes initial steps and demonstrates the potential of the respective aspect.

Authoring Support and Adaptive Stories The principal challenge in the widespread adoption of data stories is the time-intensive and technically complex process required to create them. While national news media and agencies may have the resources to make such investments, local entities often lack this capacity [37]. For example, local newspapers face constraints in terms of time and human resources, whereas local NGOs may not possess the necessary technical expertise. Therefore, authoring support is even more crucial for local data stories than it is for national media outlets. A viable solution could be the use of templated stories that local stakeholders can adopt and enrich with local context and specifics, for instance, descriptions that explain the data shown on a map [15]. These templates would follow a predefined structure and utilize predefined visualizations, making the creation process more accessible and less resource-intensive. Moving beyond templates, the research direction could involve creating stories more automatically for specific local contexts and topics. Advances in AI have enabled capabilities in visualization and text generation that support a partly automatic approach. They have lowered barriers to performing advanced data analysis and generating respective visualizations [40]. More specifically targeted at narrative visualizations, various automation approaches have been recently suggested [6]. Authoring support may start with suggestions for story snippets [36] or improving the text–visualization integration [18], and spans to automatically generating full stories [35]. Ultimately, the stories might automatically adapt to the local and personal context of the readers. Tailoring such approaches for local climate reporting can enhance *participation* by citizens, as well as may help local news media apply data journalism [37].

Dissemination and On-site Stories Like other data stories, local data stories can be disseminated as web-based narratives, videos on online platforms, or analog or digital pieces at exhibitions. However, the local context may permit a broader variety of dissemination methods. For instance, they can be integrated into citizen *participation* processes or presented at local schools and community meetings. Regional exhibitions and fairs might also offer diverse opportunities for showcasing these stories. Additionally, some dissemination formats might allow different presentation modes and new forms of interaction. For instance, on-site stories could utilize the actual current location of the user to navigate through the story, leveraging the physical *local context*. Story elements would be displayed at the actual locations that are linked to or relate to the data. Urban interaction approaches enable various forms of interaction with public displays, allowing multiple users to engage with the content simultaneously in an urban setting [22]. Furthermore, augmented reality solutions can be leveraged to visually enrich the real-world views with data story snippets (e.g., using smartphone pass-through) [21]. Or, specific locations can be modeled in virtual reality to make local points of interest accessible to anyone, regardless of their ability to physically visit these places. In the context of climate change, the stories might be presented at places where the effects of global warming can be physically observed (*specific relevance*) or at sites where mitigation strategies have already been implemented (*actionable conclusions*). In all such outreach efforts, equitable access to the presented stories should be considered, allowing alike participation of young and elderly people, low and high-income families, ethnic minorities, etc. It might not be possible to cater to everybody through a single solution, but different media and dissemination strategies complementing each other should be explored. Generally, more research should be invested in acceptance and reception studies of such data stories to tailor them to local demands.

Emotional, Social, and Ethical Aspects If data stories address individual *interest and concern*, particularly on emotionally charged topics like climate change, it is essential to consider their psychological and social impacts, as well as ethics. Certain threats may arise. For instance, readers informed about the effects of climate change—especially if not pointing out *actionable conclusions*—might feel powerless and depressed. Information presented in data stories could be misused in heated political debates, or whole stories could be recontextualized to support misinformation campaigns. The pitfalls of *sensationalism* and *clickbaiting* for news media [3] and *greenwashing* for businesses and public stakeholders [39] might affect the quality of data stories. Instead of constructively contributing to a societal debate, data stories might reinforce social divides, for instance, by indirectly condemning a social group for a specific behavior. Different levels of data literacy could exclude certain groups from the medium and debate, and it might be necessary to strive for better *data inclusion* (i.e., a more socially inclusive approach to data literacy) [4]. For instance, gamification and serious games can be leveraged to reach out to young people and kids [9]. It is crucial to consider these effects when providing support for their authoring, as well as to study the real-world impacts these stories have. Understanding these dynamics is essential for responsibly managing the dissemination and reception of data-driven narratives, as well as for convincingly inviting for *participation*. Nevertheless, the general hope is that fact-based and tangible communication of data at the local level lays the groundwork for discussions based on facts and provides starting points for constructive actions (*actionable conclusions*).

8 Conclusion

Our discussion shows that data storytelling and narrative visualization methods are valuable tools to objectively inform about climate change, potentially supporting the fight against misinformation through accessible data representations. But whereas the local perspective is critical for effective, broad-range climate mitigation strategies, we do not yet see—at least not in the limited scope studied—such storytelling methods applied to the local context. By discussing characteristics of the local scenario and showcasing different examples, we lay foundations for exploring this direction further and formulate specific challenges and opportunities. On the one hand, the local scenario provides interesting options for participation and outreach, supported through innovative use of technologies. On the other hand, the intricate debate on fighting climate change poses challenges reaching far beyond the factual presentation and technical implementation of data stories, inviting for interdisciplinary research to study the impacts of such communication efforts. Our work might serve as a starting point for exploring these directions, but by far does not offer sufficient empirical evidence for judging the existing and future application of the dicussed data stories, user preferences and reactions to such stories, their educational potential, or political implications of publishing them. With such empirical support, in the future, a *framework* of application scenarios, storytelling solutions, and impacts can be developed that more comprehensively describe *local climate data stories*.

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