From science to story: Communicating permafrost concepts with data comics

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ABSTRACT

We are creating data comics that use graphics, narratives and visualization to explain permafrost and its interaction with climate change. Despite the increasing attention to permafrost change due to its local impacts and interactions with global climate, many people without scientific background or lived experience related to permafrost do not understand what permafrost is or why it is important. This knowledge gap reduces public consideration and risk perception. We are exploring new ways to present this information to a wider audience, including policymakers, scientists from other fields, school teachers, and the general public. A major communication challenge we face is that many scientific articles are not easily comprehensible and understanding concepts such as permafrost thaw and its effect on land use and infrastructure can be challenging. To address this challenge, we are developing new ideas in creating data comics, a new format that integrates data visualization and storytelling to deliver insights from data in a new format. We are exploring the use of relatable examples and analogies to make scientific information more comprehensible to the public. We are creating data comics collaboratively with experts in data visualization, narrative construction, data comics, and permafrost science. The data comics are designed to be both scientifically informed and verified, using the best and most current scientific information available. We prioritize data transparency, working towards more understandable and engaging presentations of scientific concepts.

1 INTRODUCTION

In this paper, we harness the data-driven storytelling genre of data comics (Segel and Heer 2010; Bach et al. 2017) to convey the definition and thawing trends of permafrost to a general audience. Data comics blend narrative storytelling with data visualizations, providing an innovative approach to communicating insights from data.

Permafrost thaw matters to people globally because thawing causes the release of greenhouse gases such as carbon dioxide and methane, thereby exacerbating climate change, and to people in cold regions because of the impacts it causes locally and regionally (Pörtner et al. 2019).

Despite its growing urgency, climate change remains a divisive issue, often muddled by cultural, political, and ideological divides (Hulme 2009; Hornsey et al. 2016). The scientific literature, while rigorous, is usually not designed for consumption by those without specific scientific training. Moreover, misinformation and oversimplified messages propagated through media contribute to public confusion and inaction (Cook et al. 2017; Treen et al. 2020).

Our project explores the potential of data comics as an outreach tool. Initially popularized in the field of information visualization, data comics combine graphics, narrative, and data visualization to explain complex data-based messages in an accessible and engaging way (Zhao et al. 2015; Bach et al. 2017; Wang et al. 2019). Previous work, such as Frozen-Ground Cartoons by Bouchard et al. (2018) which focus on fieldwork and interactions with local communities, demonstrates the effectiveness of comics in communicating permafrost science through localized narratives. We extend this approach by incorporating data visualizations into comics and render the information in a digestible way, thereby bridging the gap between scientific research and public comprehension. Our interdisciplinary team—comprising experts in literature and narrative, data visualization, and permafrost science—works collaboratively to create a data comic that distills essential aspects of permafrost science, including its definition, geographic distribution, temperature trends, and the impact of often-overlooked physical phenomena on the interpretation of the temperature trends in thawing permafrost. The comic is available at: https://dc4cc.github.io/permafrost.html.

The story employs the genre of creative nonfiction to weave scientific data and historical news events into the narrative of a family hiking trip in Banff National Park (Alberta, Canada), a region with mountain peaks underlain by permafrost, and frequented by millions of visitors annually (Gruber et al. 2015). Science and data visualizations are embedded and illustrated within the comic. For example, characters draw charts on the snow (Figure 1), and explain the physical phenomena of latent heat by observing the temperature of ice and snow melting in a camping pot (Figures 2 and 3). Through these examples, we aim to make the explanations fun and engaging to the audience.

In the ensuing sections, we outline our creation process and design rationales and delve into the opportunities and challenges of using data comics for science communication, providing valuable insights gleaned from our experience.

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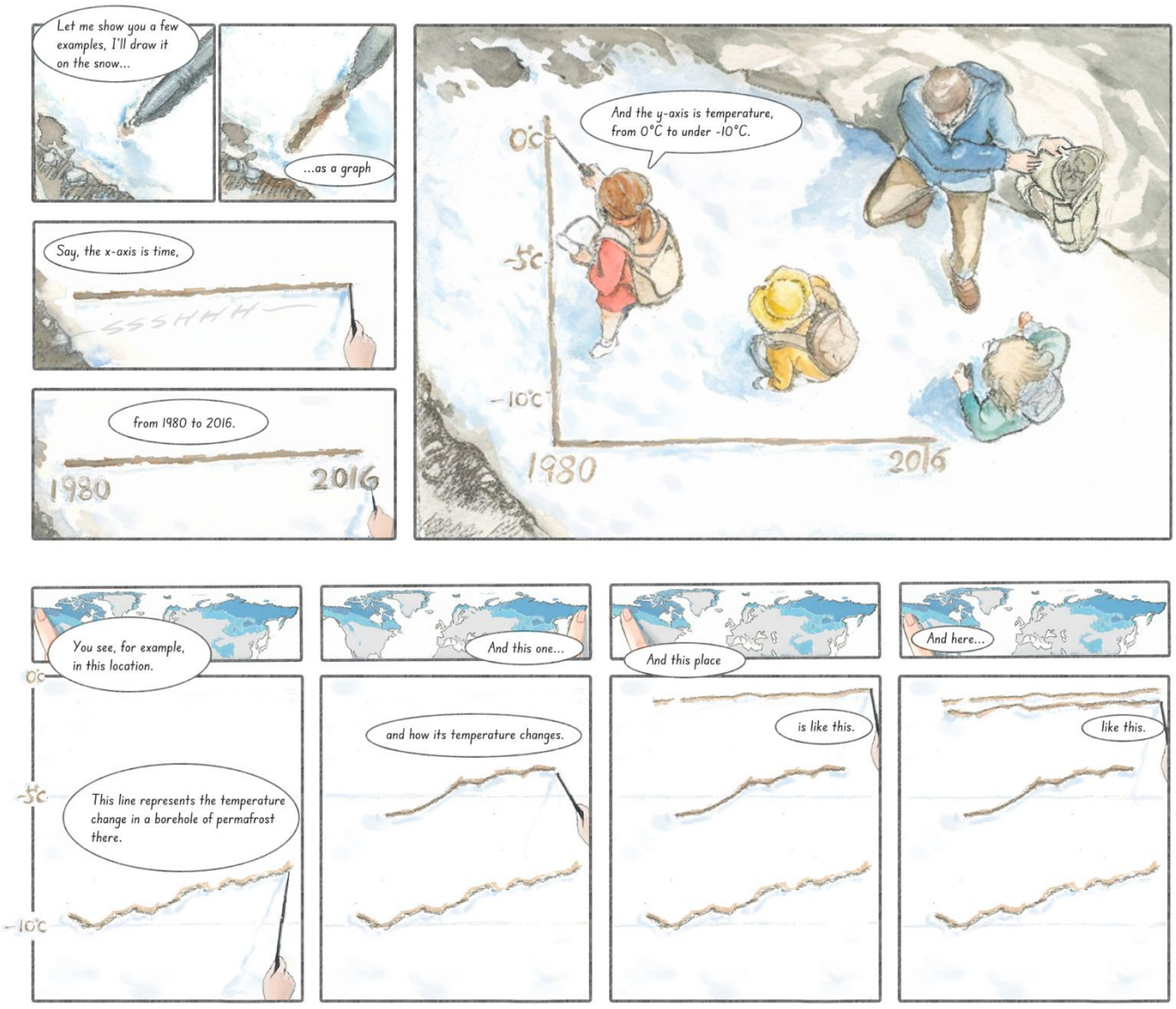

Figure 1. Snippet from page 4 of the data comic; the girl is drawing a line chart on the snow to show her family the temperature of permafrost in different locations in the world.

1.1 Background

1.1.1 Comics and Data Comics

Comics, also referred to as graphic novels or graphic stories, represent a distinctive medium that conveys narratives through an integration of visual imagery and text (Cohn 2005; Kukkonen 2013). With the powerful and expressive ability for communication, comics have been valued for their ability to promote public engagement and used as educational tools for teaching science (Tatalovic 2009; Lin et al. 2015; Farinella 2018).

Inspired by comics, data comics aim to communicate insights with data visualizations. Data comics support data-driven storytelling by making use of peoples' familiarity with reading and understanding comics along with the particular qualities of the medium (Zhao et al. 2015; Bach et al. 2017; Wang et al. 2019); they have recently gained attention in diverse areas, ranging from improving data visualization literacy (Wang et al. 2020; Boucher et al. 2023) to environmental and climate education (Hasan et al. 2022; Lc et al. 2022), and medical science (Alamalhodaei et al. 2020). The data comic we create for permafrost will incorporate *four essential components* (Bach et al. 2017): contextualize the *data visualizations* within a compelling *flow* of *narration* rather than a dry presentation of facts and employ various visual and narrative design patterns (Bach et al. 2018) to combine *words-and-pictures*.

1.1.2 Comics about Climate Change

The communication of climate change science presents a unique set of challenges and opportunities. On one hand,

the diffuse, abstract nature of climate change as well as the invisibility and lack of immediacy of some climate phenomena can create barriers to public understanding (Moser 2010). On the other, the immediacy and urgency of climate change issues require public engagement for effective action (Corner et al. 2014). By fostering a deeper and more enduring engagement with the scientific subject matter, comics contribute to a richer, more nuanced public discourse on climate change and its implications. By incorporating maps, charts, and scientific diagrams, comics are found to create more understanding of climate change (Reumont et al. 2023), to engage with environmental problems and determine attitudes (Topkaya 2016; Munawwaroh et al. 2018; Maggiulli 2022), and to promote a willingness to take actions to protect the climate (Theodorou et al. 2019).

Several works inspired the design of our data comic, for example, an anthology of comic strips about climate change and animal extinction (Goodenough 2021). Regarding examples involving data, a 9-page comic in the journal Nature demonstrates the history of global policy around climate change (Monastersky et al. 2015), and a set of stories with visualizations to show alternative realities of environment (Lc et al. 2022). The use of comics for educating the public about permafrost has proven successful. For example, Frozen-Ground Cartoons by Bouchard et al. (2018)—a collaborative initiative between artists, science communicators, and permafrost researchers—uses everyday language in dialogue and short narratives to clarify the basics of permafrost. By further incorporating interactive elements like augmented reality and board games, this initiative has succeeded in captivating a broad audience, including school children, educators, and the public at large. Our work sits in the genres of data comics and science comics to engage non-specialist individuals and focuses on elucidating the science and data about permafrost.

2 METHODOLOGY

Our methodology for developing the data comic consisted of four primary phases: 1) establishing communication objectives, 2) formulating data visualizations and a script, 3) producing an initial draft of the data comic, and 4) refining through iterative design. Below, we delve into each phase to elucidate our approach.

2.1 Creation Team

The creation team was initiated by three members. A post-doctoral researcher whose research focuses on data-driven storytelling with data comics took the main role in designing the data comic. A professor whose primary research areas are information visualization and interaction design mentored the creation process of this project. A professor whose research focuses on permafrost and related phenomena in high-latitude and high-elevation environments provided resources of scientific explanation, i.e., publications and empirical experience, and made sure the science was properly explained. Two members, a professor, and a M.A. student in literature, later joined to help iterate the story. The team met every second week to discuss the progression and decisions.

2.2 Communication Goals

A clear articulation of communication objectives is fundamental in shaping the language and design of our data comic. Unlike more commonly understood climate concepts such as fossil fuels and greenhouse gases, the term ‘permafrost’ is less familiar to the general public and is often shrouded in misconceptions. As such, we opted to focus on imparting basic knowledge about permafrost and dispelling prevalent myths. Since groups with an interest in permafrost will keep growing and changing (Gruber et al. 2023), we created this comic aiming to be understandable and engaging to a diverse range of people.

2.3 Story Development

Since the data comic designer investigated this project as a novice about permafrost, they brought a non-expert perspective. To familiarize themselves with the subject matter, the designer engaged in discussions with the team’s permafrost scientist, focusing on key questions such as: 1) What foundational knowledge is crucial for comprehending the role of permafrost in climate change? 2) What are the prevalent misconceptions surrounding permafrost? 3) What research methods are commonly employed in permafrost studies, including techniques for data collection? By addressing these inquiries, the designer aimed to gain an in-depth understanding of permafrost and its significance, as well as to identify the key concepts that should be incorporated into the data comic. The designer then formulated a list of key messages to be conveyed according to the discussion and scientific publications and afterward, drafted an initial story script, supplemented by relevant data and visualizations. We initially conceived three alternative storylines imparting the same targeted messages. After extensive team discussions, we decided on one and refined the script before advancing to subsequent visual design phases.

The story employed the notion of *faction*, combining elements of fact and fiction to make verifiable and justifiable claims to truth and simultaneously engage readers (Bruce 2019), and *creative nonfiction* that provides information about a variety of subjects, enriched by relevant thoughtful ideas and personal insight, without exaggerating or making up facts and embellishing details (Gutkind 2012). Our story is a melange of real-world scientific data such as data on global permafrost warming (Biskaborn et al. 2019), historical events such as the demolition of Abbot Pass Hut (Parks Canada 2023), and imagined activities during a hypothetical family hiking trip, aiming to weave multifaceted, accessible factual information into an emotionally resonant story.

2.4 Visual Design Process

Initial drafts created as rough sketches enabled swift changes based on feedback from the team. The comic was then colored with watercolor, its transparency and fluidity being aesthetic features that provide a unique condition for

illustrating the graphics of thawing permafrost. After the coloring stage, the comic was scanned to facilitate digital editing. Adobe Photoshop was used for the bulk of the digital work such as color correction, fine-tuning graphics to ensure accuracy in maps and data visualization, and text insertion. Stable Diffusion was then used to fine-tune the details of characters.

To iterate the data comic, external feedback was obtained from four permafrost scientists. The reviewers were generally positive about the comic's effectiveness in communicating permafrost-related concepts and provided specific suggestions including clarification in certain panels, word choice for increased precision, and minor adjustments to graphical elements for enhanced comprehension.

3 Story and Data Comic Design

The story unfolds during a family hiking trip along the boundary of Banff National Park in Alberta and Yoho National Park in British Columbia. After setting the scene and introducing the characters, the family encounters a plaque that talks about the Abbot Pass Hut, a historic base for mountaineers, which had to be demolished in June 2022 due to permafrost-induced landslides (Parks Canada 2023). This event prompts a conversation about the role of thawing permafrost in the hut's demise.

In a novel twist, we subvert the usual parent-child dynamic: the children, not the parents, offer informed explanations to engage proactively in environmental issues, including permafrost. The son's query about the existence of permafrost in southern Canada opens the door for a discussion about what permafrost is and where it is found. The father's misconceptions serve as teachable moments. He incorrectly equates snow and glaciers with permafrost, and his daughter corrects him.

The story is moved forward as the daughter corrects her father by referring to a fictional brochure named *Mountain, Climate and Ice: Understanding and Seeing Impacts of Climate Change Above and Below Ground on Your Hike*, then by drawing line charts of temperature change of permafrost (Figure 1) in the snow. The *Multiple-Explanations* data comic design pattern is employed by presenting the process of drawing the chart to guide the audience through the mapping of locations to the lines on the chart. In accordance with the recommendations from Kosslyn (2006) and Harold et al. (2016) to include only essential information for the intended communication purpose, we have chosen to highlight four key lines from the original chart presented by Biskaborn et al. (2019). The central message is that while the temperature of permafrost is generally rising, the patterns of increase vary. Specifically, permafrost locations with lower temperatures are experiencing a dramatic rise in temperature, whereas those closer to zero degrees Celsius are seeing a more modest increase. Interpreting these differing trends requires counter-intuitive thinking and knowledge about phase change as context.

To address her father's skepticism, the daughter seizes the opportunity to offer a hands-on explanation, embodying the principle that a small experiment, instead of a long explanation, is a good educational tool. As the father begins

to scoop snow into a camping pot for cooking pasta, she places a thermometer in the snow to monitor its temperature (Figure 2). Concurrently, she sketches another line chart in the snow (Figure 3). This exercise serves to illustrate the concept of latent heat, explaining why the temperature might hover around zero degrees Celsius during phase changes, such as during the thawing of permafrost. The father's doubt is shattered when, in a moment of dramatic tension, a bus-sized rock falls nearby, underlining the immediacy and unpredictability of permafrost-related hazards. The story concludes with a family discussion about the need for immediate action, leaving the audience with both a greater understanding of permafrost and a sense of urgency regarding its environmental impact.

Figure 2. Measuring the temperature of melting snow with a thermometer to illustrate the concept of latent heat, which is not reflected in temperature changes.

4 Discussion

4.1 Data Visualization in Narration

Data visualizations, such as temperature-depth profiles, scatter plots, and heat maps, are abstract by nature and demand a certain level of data and visualization literacy for interpretation. Given that the comic is designed for the general public, it is essential to select visualization techniques comprehensible for the audience with limited data and visualization literacy. A notable example is

'warming stripes' by Ed Hawkins for the 2018 IPCC report, which uses colored stripes to intuitively depict temperature changes over time (Hawkins 2018). In our data comic, basic line charts serve to illustrate various aspects of permafrost temperature changes, both annually and across different locations, as well as the temperature dynamics of melting snow. To ease the reader into the visual language, we introduce visual mapping and components gradually by breaking the chart into many comic panels.

Incorporating data visualizations naturally into a hiking narrative posed a challenge. We overcame this by utilizing elements within the story's setting—for example, using a visitor brochure or drawing on snow with a hiking stick. While some visualizations, like the layered underground diagram, were not integrated through story-specific materials, they were directly overlaid on the comic panels, serving a function similar to a voice-over.

Using analogy and metaphor is integral to scientific thinking (Ortony 1993). Metaphorical concepts are 'those which are understood and structured not merely on their own terms, but rather in terms of other concepts' (Lakoff et al. 1980, p. 195). Ortony (1993, p. 450) outlines six principles for analogical reasoning we found also applicable to the use of visual metaphor in data comics. In our work, we employ the metaphor of cooking frozen meatballs to represent the hidden transformations occurring within permafrost—an ongoing process yet not immediately visible. Similarly, we use the melting process of snow as an analogy for the thawing of permafrost to explain the latent heat. Although two bases (i.e., snow and meatballs) are employed to map permafrost, each focuses on separable aspects. We think involving data visualizations and visual metaphors in the comic can support scientific explanations, and benefit audiences by improving their data and visual literacy. Presenting science diagrams and data visualizations in an artistic way (e.g., hand-drawn line chart on snow) could make the story fun and engaging.

4.2 Promoting Credibility

Trust is a key factor in gaining public acceptance for risk assessments and policy recommendations (Poortinga et al. 2003). The information deficit model, which views the public

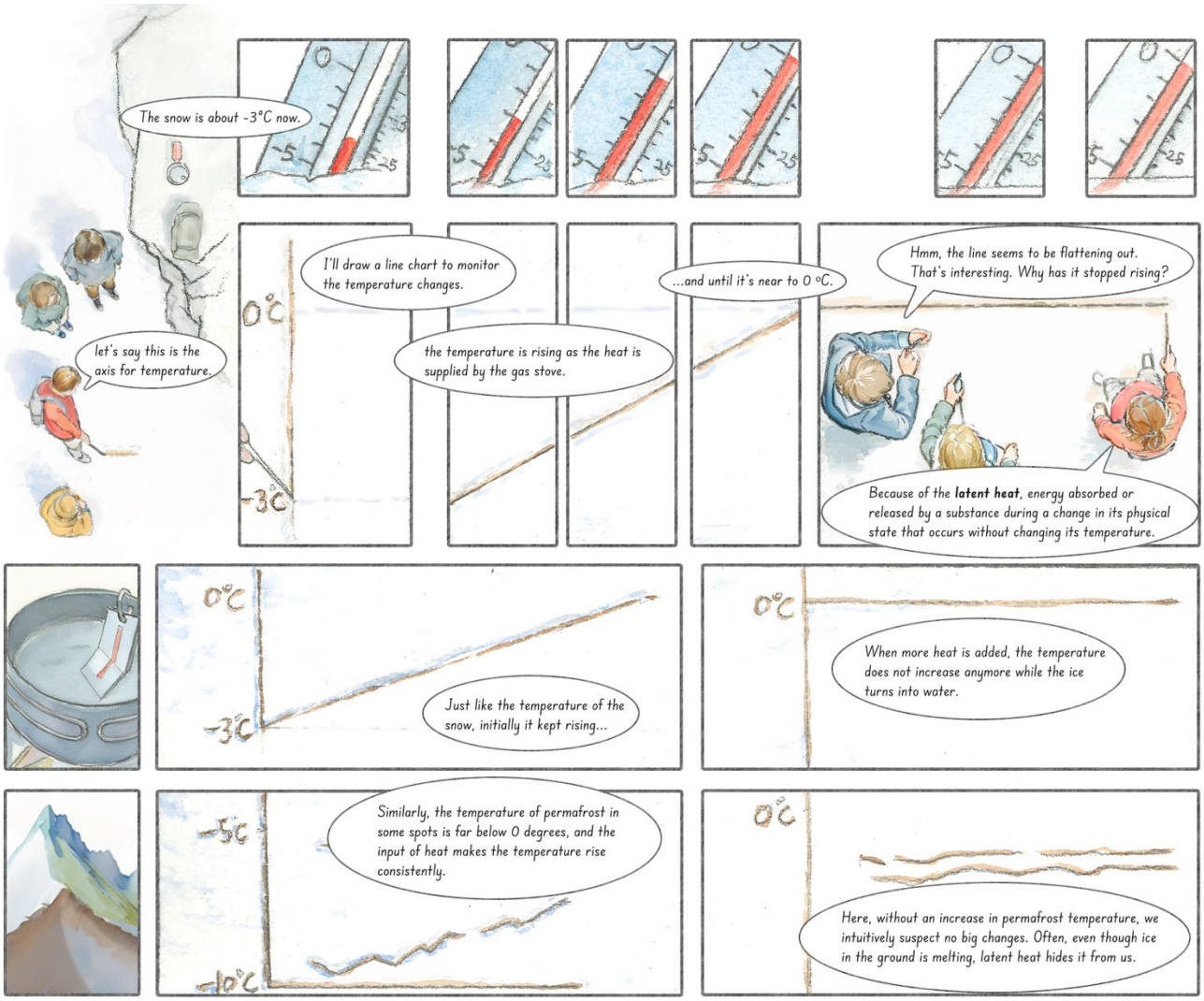

Figure 3. The daughter explains the physical phenomena of latent heat by drawing a line chart demonstrating temperature change of snow melting and compares that with thawing process of permafrost.

as generally lacking in knowledge and needing education, is increasingly giving way to a more nuanced understanding of a public that is informed, engaged, and scientifically literate (Miller 2001; Sturgis et al. 2004). While we recognize that trust is shaped by various complex factors such as ideology, cultural background, and political affiliations, as well as information sources, simply providing credible data is not enough to ensure belief. However, the deficit model continues to be a cornerstone in science communication, featuring prominently in various climate change communication efforts (Davies 2008; Suldovsky 2017). Our data comic aims to uphold the principles of authenticity, accessibility, and transparency. All data used in the comic are sourced from peer-reviewed scientific publications and the comic was verified by the team's permafrost scientist and other four permafrost researchers for accuracy. We intend to regularly update the comic to ensure that it remains current, relevant, and unambiguously correct for readers with diverse backgrounds and perspectives.

4.3 Engaging Collaboration

Crafting data comics necessitates a blend of interdisciplinary expertise, including storytelling, data analysis, visualization, visual design, and illustration. When the subject matter involves specialized domain knowledge like permafrost, effective teamwork across various roles becomes both a challenge and an opportunity for integrating diverse perspectives to overcome communication barriers. Utilizing an ethnographic approach to incorporate local stories into data comics can further connect scientists and local communities.

5 Conclusion

In this paper, we detail our process of crafting a data comic that serves as an educational tool for introducing permafrost (https://dc4cc.github.io/permafrost.html). We outline our design rationale and discuss how data comics offer a promising avenue for effective communication by seamlessly intertwining data visualizations with scientific knowledge and narrative techniques.

6 Acknowledgements

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