

Glacial Till

Elizabeth H. Case, Andrew Hoffman,
Hannah P. Mode and Tyler Rai

Introduction

Glacial Hauntologies, our art-science collective, is an ongoing effort to dissolve boundaries between contemporary art practices and glacier science research. Through a shared ethos that each field actively shapes and “entangles” with the other (Barad 2006: 94), we exchange methodologies, conceptual knowledge and disciplinary practices through discussion, experimentation, tutorials, processing and making.

In this essay, which draws from Renee Gladman’s “prose architectures” (2017), we produce a visual entanglement of artistic and scientific concepts, processes, infrastructures and sources. The content—photographs, video stills, journal excerpts, glaciological data, sketches and fragments from performance texts—relates to the interaction of human and glacial bodies over vast temporal and spatial scales. The images begin as clearly ordered and described, sometimes extremely technically, clarifying meaning to some audiences and obscuring it to others. Then, slowly, like the rocky sediment underneath a glacier, the content is reworked: repeated, glitched and manipulated, with Case’s handwritten text from an Antarctic field season, Rai’s poetry and spoken word, logistics contracts and quotations. From and within these interactions, material is moved, shaped and mixed. An unsorted, unstratified glacial till emerges, assembling, moraine-like, into this collaboration.

Polar fieldwork requires extensive infrastructure: aeroplanes, buildings, tents, polar clothing, sleds, ships, fuel, food, helicopters, skidoos, planning documents, contracts, inventories, emails, tickets, signatures. There are also bodies—ice and human—working, observing, translating and remembering. By entangling glaciological concepts and bodily processes, archival data and performance, this essay exemplifies the overlapping, deforming, transforming infrastructures of human memory, bodily perceptions and glacial change.

THE IMAGE IS NOT THE GLACIER!

THE DATA IS AN ECHO WHICH CAN HELP US

FIND A SHAPE!

No. 23a-c. Inclination of vertical lines. Sample 254, x2.9.

- a) $\theta = 16^\circ$, $\phi_0 = 0.5^\circ$,
- b) $\theta = 34^\circ$, $\phi_0 = 3.0^\circ$,
- c) under crossed polaroids.



"ice transcends the boundaries of bodies,

ice produces its own order of things."



we start by
displacing our
voices, frac-
turing them
around the

room like particles. one piece of the whole, one frequency out of a spectrum of sound, re-forming into a choir of disparate waves.

Samples without MPI Permit Requirement

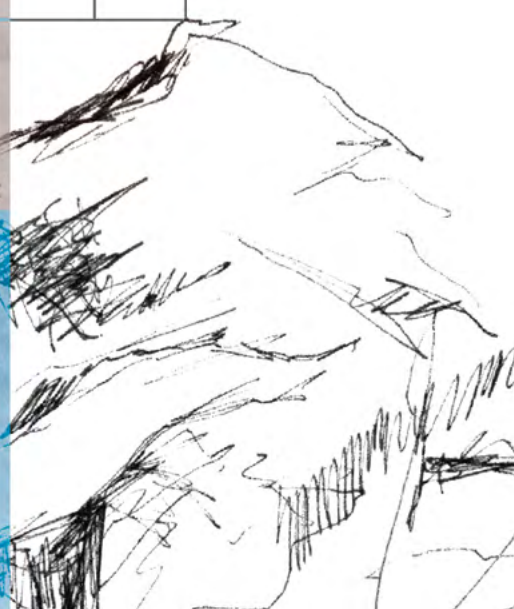
Add any samples that do NOT require a MPI permit here. All information is required. If you plan to send any of your samples to multiple facilities, you can list all samples of a single type in one row and note in the comments box below that you will be sending the samples incrementally throughout the season.

Sample Name	Quantity	Container	Material	Location	Depth	Depth Interval	Depth Interval	Depth Interval	Depth Interval	Depth Interval	Date Rec'd	Date Returned	Date Rec'd	Date Returned	Comments
											Washington	15 Apr 2023			

Describe your sampling plan (date or week, location, depth, etc.) as clearly as possible.

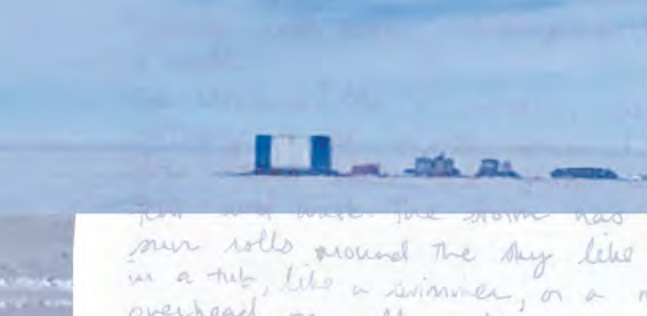
These samples will be collected using the following sampling strategy: [Handwritten notes describing sampling strategy]

Additional information of comments, including any sample receipt #s.



for many...
 early astronomical observations...
 the pack is...
 can...
 death... see my hand...
 walking, light as any...

... and set out...
 above and feel that...
 chips; frozen salt water is...
 on a compass bearing...
 and compass, see the ice so...
 low atmosphere...
 walking, light as any...



For a while, the storm has
 over rolls around the bay like
 in a tub, like a swimmer, or a
 overhead on all sides.
 [My name is Silence. Silence is
 I robe myself in the morning
 a chip from the pack ice fills
 my brain pan grows glaciers,
 The years are passing here.
 Far ahead is open water. I
 I have walked into the silence like
 horizon's spread aims which wid
 to the rim which calves its
 at the edge and look ahead.

Staging/Storage Space :: Storage Space List

Temporary Storage Space Requirements

Item Description	Approximate dimensions of items to be stored	Total Item Wt. (lbs.)	Keep Dry	Do Not Freeze	Fragile	Hazardous	Radioactive	Secured Area	Cooling Needed	Comments (if applicable)
radar an ancillary equipment.	Fits in (43" x 43" x 36") triwall	500			X					miscellaneous radar equipment that may be needed on Thwaites Glacier.
Date Temporary Staging Space Needed: Start Date 12/01/2022 End Date 01/31/2023										

Describe any additional temporary storage space needs in detail:
 Storage in science cargo cage would likely be sufficient.

Over-Winter Storage Space Requirements

Item Description	Approximate dimensions of items to be stored	Total Item Wt. (lbs.)	Keep Dry	Do Not Freeze	Fragile	Hazardous	Radioactive	Secured Area	Cooling Needed	Comments (if applicable)
radar electronics	Fits in (43" x 43" x 36") triwall	500	X	X	X					radar electronics that may not need to be returned but will be used in the 2023-2024 field season
radar sled elements	Fits other: details explained below	2400								radar sled antenna elements
Date Over-Winter Space Needed: Start Date 02/06/2023 End Date 11/15/2023										

Describe any additional over-winter storage space needs in detail:
 Cage would be sufficient for storage of radar electronics.
 If the radar system fares well in the field, we may wish to store radar antenna elements over winter. These antenna elements can be stored outdoors, potentially stacked. They are approximately 3'x3' and weigh 150 lbs per unit. There are 16

So I will try to explain how partial

we recognize

the mingling

with

/sea/

/shoreline/

/stone/

transition

finding the

tether

along the lines

of stress

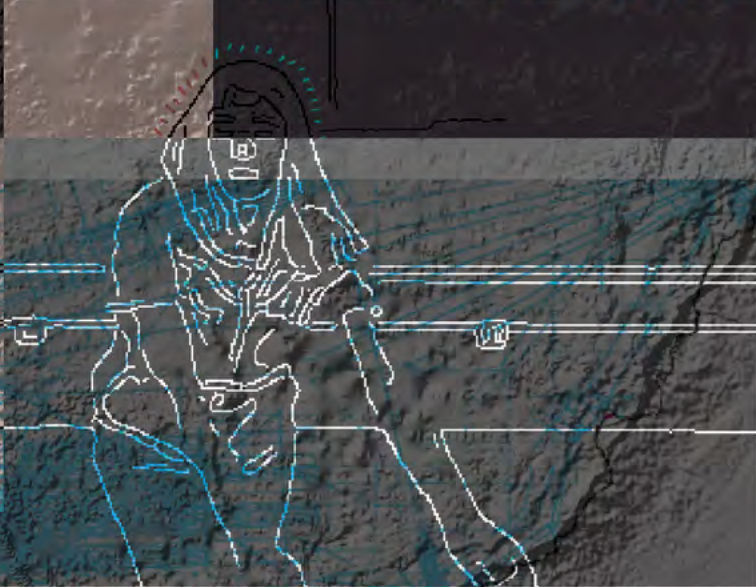
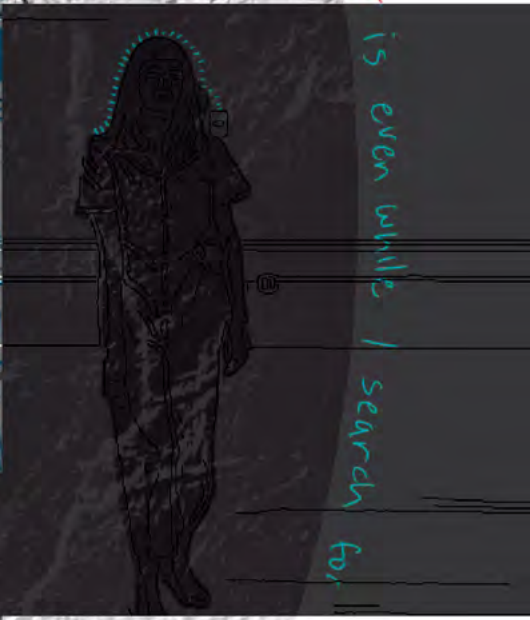
and strain

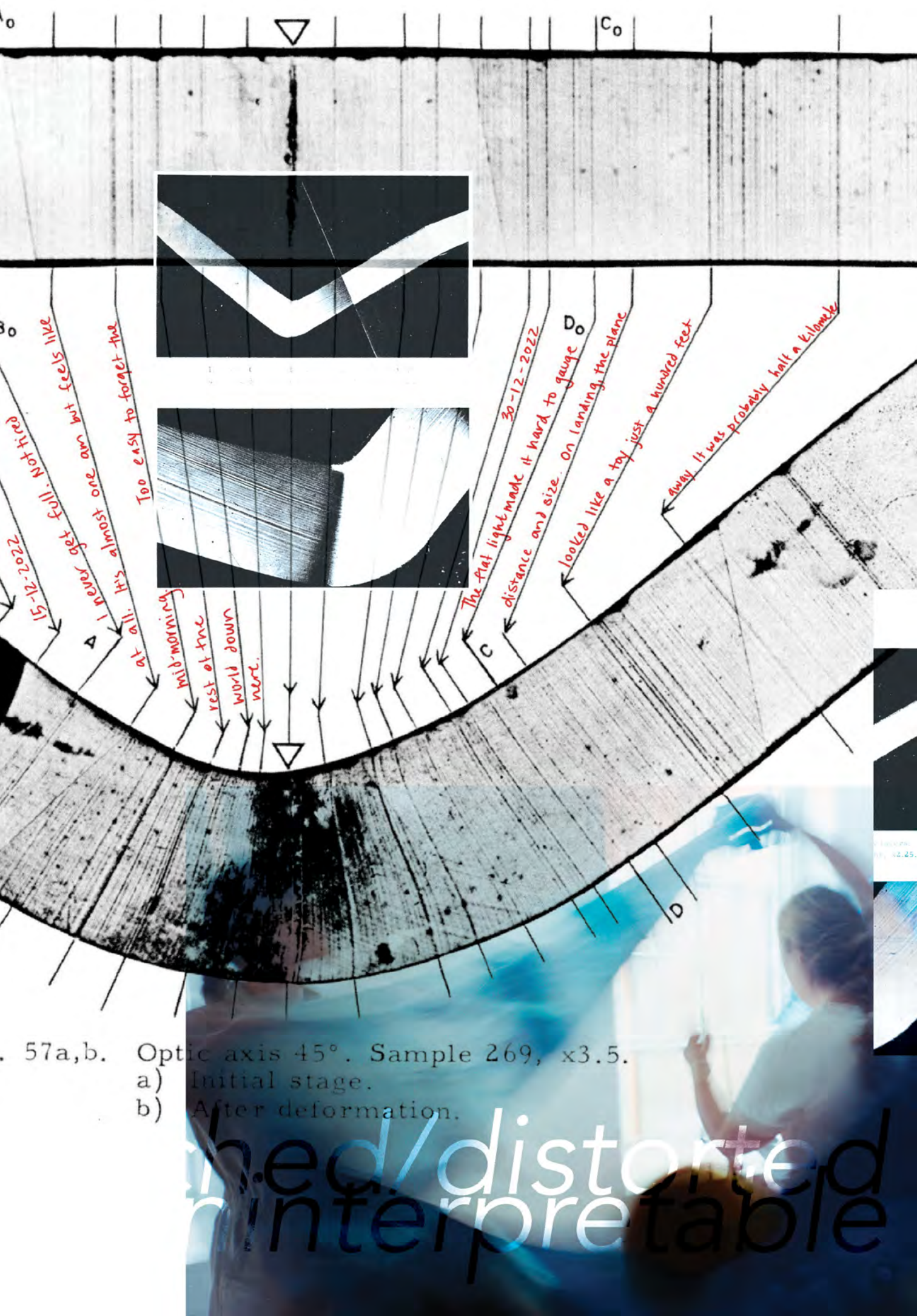
making paths

along the wake

this vision

of a glacier is even while / search for,





57a,b. Optic axis 45°. Sample 269, x3.5.
a) Initial stage.
b) After deformation.

med/distorted
interpretatable

de
r
a

If I don't move all I hear is



the faint ringing in my ears from the echo of the day.

of
a
r
o

1. Ukichiro Nakaya, a twentieth-century Japanese snow scientist, ran a series of experiments in the 1950s to study how ice responds to stress, or applied force. The strength of ice and the way it responds to stress have implications for how we understand and model ice flow. These images show a sample of single, large ice crystals (up to 40 cm) from the Mendenhall Glacier, which drains from the Juneau Icefield in southeast Alaska.¹ “The deformation of single crystals of ice shows a peculiarity,” he wrote. “The specimen apparently has a structure like a stack of papers and deformation takes place by bending of this ‘paper’ and gliding between the ‘papers’” (Nakaya 1958: 2). Recently, we have begun to be able to measure the stacked, hexagonal crystal structure of ice at larger scales, outside of laboratory measurements of ice cores. In 2022–2023, Case and Hoffman traveled to Thwaites Glacier in Antarctica as members of G.H.O.S.T. (Geophysical Habitat of Subglacial Thwaites) and a part of the International Thwaites Glacier Collaboration. There, they took radar data that recorded the glacier’s *ice fabric*, the orientation of ice crystals that is part of a glacier’s response to stress that is applied over long timeframes and across large spatial scales. **2.** A declassified aerial photograph of Thwaites Glacier in Antarctica circa 1963, taken as part of Operation Deep Freeze by the U.S. military, which remains the largest deployment of science personnel to the continent. Scientific research in Antarctica is inextricable from geopolitical contexts and military influence and relationships. The military provides much of the infrastructure for the U.S. Antarctic program. **3.** Operated by the British Antarctic Survey, the *Caboose* is a converted shipping container that Case lived out of while doing fieldwork on Thwaites Glacier. It is pulled on skis by a PistenBully, attached between the vehicle and sleds holding fuel and equipment. **4.** A manipulated video still of Rai dancing. Rai reviewed coherence plots from the radar data of ice fabric collected and processed by Case (2024) and improvised short, looping choreographies in response. Stills from the video that Rai took of the choreographies were run through an edge-detection algorithm and are part of an ongoing piece centered on the concept of *coherence*, which can be variously defined as a mathematical measurement of signal similarity, the emergence of sense and/or consistency (e.g., thoughts ‘cohering’), and/or different parts fitting together to form a whole, a ‘coming together’. **5.** These show observations of ice fabric on Thwaites Glacier, taken with two different ground-based radar systems by Case and Hoffman. In both figures, the difference between two orthogonally polarized, co-located measurements helps us understand the strength of the ice fabric, which affects its viscosity—that is, its internal resistance, the sluggishness of the ice as fluid. Ice with a higher viscosity flows more slowly than ice with a lower viscosity, and is a key property for understanding how quickly Thwaites Glacier may retreat in the future. **6.** Field sketches from the Juneau Icefield by Mode. **7.** The top image shows Mode rinsing a cyanotype fabric print in a stream on the Root Glacier near McCarthy, Alaska, made during a collaborative artist residency that explored embodied research. It is part of an ongoing series of large-scale photographic ‘blueprints’, of glacial features made in the field to memorialize human connections to ice. The bottom image shows a cyanotype print on paper, made with a glacial erratic—a rock that has been moved by a glacier from its geologic origin to a new location. **8.** Excerpt from *An Expedition to the Pole* by Annie Dillard (1992), handwritten by Mode. **9.** A grayscale map showing the bed topography beneath Antarctica. **10.** *SIGNAL* is a sculpture consisting of a collaged cyanotype sail, glass vessels and suspended ice cores. The sail, a 40-foot collage of cyanotyped fabric, is rigged with a series of pulleys and knots. The tension of the sail’s suspension alters as the ice melts, creating real-time shifts in the sculpture.

¹ Case and Mode help organize and teach on the Juneau Icefield Research Program, where samples were collected in the 1950s.

The cyanotype textile collage draws on the communicative logics of flags and the mnemonic intimacy of quilts, echoing how ice fabric records a glacier's deformation history and shapes its future flow. Top: Installation in Mode's studio by Makenna Finch. Middle: Rai adding grommets to the sail. Bottom: fabric details, including a plot from Case's ice-fabric measurements. **11.** Available flight data for Greenland and Antarctica, which comprise the Bedmap2 datasets: an archival dataset of the ground underneath Earth's largest ice sheets, an interpolated interpretation of the airborne radar data (Fretwell et al. 2013). **12.** A text exchange between Mode and Case. **13.** A finite-modeling domain for glaciers that flow into the Dotson and Crosson Ice Shelves, showing the surface speeds that are part of a global glacier mesh, where a mesh is the number and geometry of elements in finite element analysis. By iteratively solving for the stresses in the ice and conveying mass through the domain, we model how glaciers and ice sheets respond to climate. **14.** Glass vessel for ice melt, designed by Rai. Hand-blown between an ice block and granite boulder. **15.** Radargram—showing the return energy as a function of depth within the ice along a profile collected by towing the radar behind a snowmobile—capturing a basal unit from northeastern Greenland near the EastGRIP ice core camp. These basal units, pervasive in northeastern Greenland, are linked to fabric changes with climactic transitions and ice (NEEM community members 2013; Franke et al. 2021). **16.** Map of ice sheet beds in three dimensions using multi-element radar technology. This map was generated from data collected on Thwaites Glacier in 2009, revealing subglacial landforms common in deglaciated environments. **17.** As part of all fieldwork supported by the U.S. Antarctic Program, scientists fill out a Supporting Information Packet (SIP), which defines the scope of the project. This SIP described the work of the 11-165 EAGER project on the McMurdo Ice Shelf.

Glossary

Coherence: Coherence has a multitude of definitions, ranging from mathematics to philosophy to everyday parlance. Mathematically, coherence defines the relationship between two orthogonal, co-located radar signals and is one measure we use when processing and analysing the ice fabric data from Thwaites Glacier. To calculate the coherence, we compute the cross-correlation and autocorrelation between the two radar measurements to understand the similarity of those measurements, given a lag or offset in time or space.

Cyanotype: Originally used by the nineteenth-century botanist Anna Atkins to document plants and algae, cyanotype printmaking involves applying UV-sensitive chemicals to fabric or paper. When exposed to sunlight, these chemicals turn the material a vibrant blue. Atkins' botanical cyanotypes signify historic artistic approaches to researching and communicating scientific phenomena.

Hauntology: Hauntology is a word adapted from the social sciences. It was popularized by Jacques Derrida (1994). It is a compound word—haunt + ontology. Ontology is a branch of philosophy focused on the nature of being and how entities relate to one another. Hauntology describes how the present is affected by the culture, concepts and context of the past, as well as the weight of failed futures. These past and future 'ghosts' reach through time, changing meanings and relationships in the present.

Ice Fabric: Glacial ice has a hexagonal crystal structure. The orientation of the ice crystals affects the physical and electromagnetic properties of ice. The bulk orientation of ice crystals in a glacier is called the ice fabric.

Till: Unsorted glacial sediment.

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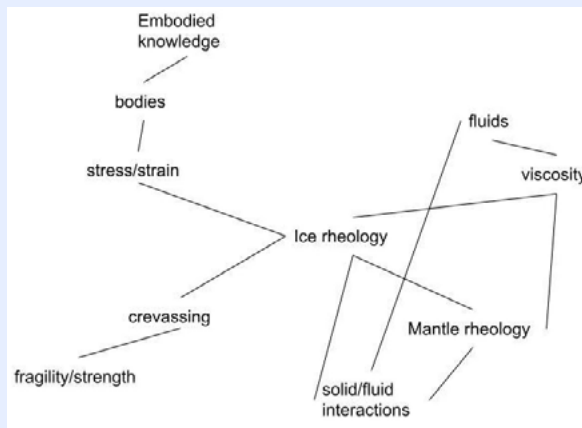
Open-ended Questions:

1. How does the architectural imaginary and the entanglement of data, glacier imagery, artworks and notes make seemingly intractable climate losses tangible and visible?
2. In the appendix, you can find all of the images in the collage. Which images stood out/were relatively easy to identify? What was obscured?
3. How do you make a scientific concept or mathematical equation visible and/or transform it into a process?

Practical Exercises:

- I. Print out one page from an academic article or report about a topic related to the earth and climate sciences. Particularly good options are review articles, including reports such as those by the IPCC, which focus on one subject at a time. Choose a word that appears many times on the page (usually something that the article is about, like 'climate' or 'ice' or 'action'). Circle each instance of this word, then connect them together using a colored pencil or highlighter. You may also choose to connect all the corners and centers of the page to each other using a different color. What did you notice when searching for the words? What did you glean about the topic and/or the way it was written? What is left, when we draw over these words, when we connect them together? Inspired by Sol Le Witt's "[From the Word 'Art': Blue Lines to Four Corners, Green Lines to Four Sides, and Red Lines Between the Words on Printed Page.](#)"
- II. Place a piece of tracing paper over one of the pages of this article. Trace at least three elements (shapes, words, lines, etc.) that catch your attention. Find in the appendix the images that correlate to the features you have traced. Based on the image descriptions, write about what new connections you can form between these elements.
- III. Cut out each image from the appendix. Arrange them according to a logic that only you know (by color, by similar shapes, by scientific concept, etc.). Share your arrangement with a partner and discuss the interconnections you each formed through your image compositions. How can this process of rearranging and generating connections inform art-science collaborations?
- IV. Scientific and artistic collage: this article weaves together scientific, artistic and humanities concepts in a glitched collage, and in doing so communicates the ways art and science can come together to allow something new to emerge. This can be done digitally using, for example, Affinity Designer or Affinity Publisher (which are free), or on paper, using scissors and glue.

1. In groups of 2–4, choose a topic you know something about, e.g. that you have been studying in class or that you have been doing research on. Ideally, this is a concept that has been or could be examined from many different points of view.
2. Define this concept using a variety of different types of sources, as well as your own phrasing—try for at least five. Record your sources so you can find them again.
3. Write the central concept in the middle of a piece of paper. Start writing down words that feel related to it. This should be quick, off the top of your head, without research. Start drawing lines to the connected ideas, to map out how your initial concept could or does interact with something other than your primary discipline.



4. Find two articles on this topic, including figures. Older scientific journals are particularly good for this, as the images are often more abstract, simpler and/or less text heavy, and the text is often also simpler. Many have been digitized and so are readily accessible. The 1940s–80s are great for glaciology, for example.
5. Collect related materials (quotes, images, your annotations, email exchanges, equations, file structures, etc.).
6. As you start your collage, it may help to set an intention or keep a particular connection or phrase at the forefront. Let this guide where you place each image, piece of text, etc. This can be driven entirely by intuition, or if you want to try to impose some structure related to your concept, then do so and note the constraint explicitly.
7. This work does not all have to be done as a group; it can be iterative and overlapping. Perhaps you each begin separately and then try to bring your work together into a single aesthetic. Perhaps one person starts, and then passes it to the next person. There should be an element of exchange throughout. If you are doing this on your own, give yourself a day in between drafts of the collage—time here is your collaborator.

8. Finally, each member of the group reflects on the process by writing about 250 words on the concept, what they learned about it, the sources they used, and how the process helped them (or not!) engage with the topic. What connections did you find? What did you learn about related work? What surprised you? What left you unfulfilled?

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Authors:



Elizabeth H. Case is a genderfluid scientist, writer and artist living between glaciated, deglaciated and flood-prone landscapes. They are currently Postdoctoral Researcher at Utrecht University in the Netherlands, modeling the surface of the Greenland Ice Sheet.



Andrew Hoffman teaches in the Earth, Environmental and Planetary Sciences Department at Rice University, Houston, TX. He studies ice-sheet processes, ice-sheet remote sensing, sea-level geophysics and coastal vulnerability.



Hannah P. Mode is an interdisciplinary artist, researcher and educator whose work integrates arts-based research with environmental science. She is pursuing a PhD at the International Arctic Research Center at the University of Alaska Fairbanks.



Tyler Rai is an artist and researcher who works across live performance, narrative essays and experimental sound works to explore ecological transformation. She is pursuing an MFA in Environmental Art and Social Practice at University of California, Santa Cruz.

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