Interviews with Greenland's Ice: Perspectives from Art and Science

Abstract

Although artists and scientists often work together for a visual rendering of scientific concepts and information, rarely do the two come together in a such a close-knit, equal collaboration, in which the germination of the idea and the weaving together of art and science result in an oeuvre in which the scientist explains the science to the artist and the artist gives the artistic view of the science itself, allowing the public to enter the art in order to see the science. The data remains the same, with two different media providing different interpretive perspectives.

In this project, five specific events in the history of the Greenland ice sheet are "interviewed", showing how the art and science are interlinked. "Interviews" is a multimodal art installation that seeks to provide viewers with an embodied understanding of glacial change. Through a range of scientific and artistic methodologies we identify distinct phases of knowledge-building about Greenland's ice as opportunities where texture, form, and diverse data can provide openings for encountering an otherwise overwhelming or threatening reality. Through "Interviews," viewers are invited to see in Greenland's past possibilities for a different future.

Keywords

Art science; data physicalization; scientific visualization; glaciology; Greenland ice core drilling; subglacial materials; Greenland ice sheet

Introduction

There is enough ice in Greenland that, if it melted, global sea level would rise twenty-five feet. It has not always been this way; the ice has waxed and waned, driven by the shifting of tectonic plates and variations in climate. Scientists have long sought clues to piece together this history, because we hope that somewhere in that past we can learn something about our future: if the ice has fluctuated without human influence, what might it do now?

Although changes in Greenland's ice sheet impact the whole world through their effects on global sea level, for most people on the planet it is a far-away frozen place that they will never visit. A perennial challenge for ice-sheet scientists is to get across the importance of caring about these places, a practice that is often learned from first-hand experiences in the field. Diverse datasets that give us insights to the ice sheet's behavior might serve as openings for standing of the planet. Scientists often com-

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Figure1. Physicalization of Greenland's ice sheet loss rate based on recent satelite readings.

VISAP'24, Pictorials and annotated portfolios.

connecting distant places with our own under- but these representations come from datasets with unique textures and represent processes with multi-dimensional implications.

Art and Science - Interviews

As a scientist drawn to art and an artist drawn to science, we wondered: can the diverse data used to reconstruct Greenland's history help us develop an embodied connection with the biography of the ice sheet?

Artists are often called upon to illustrate science and many artists work with scientists as a source for the themes within their art. Here we are aiming for work able to function in both of those dimensions, a work in the language of art that bypasses our intellect and speaks to our soul, while also conveying the research and motivation of the scientists.

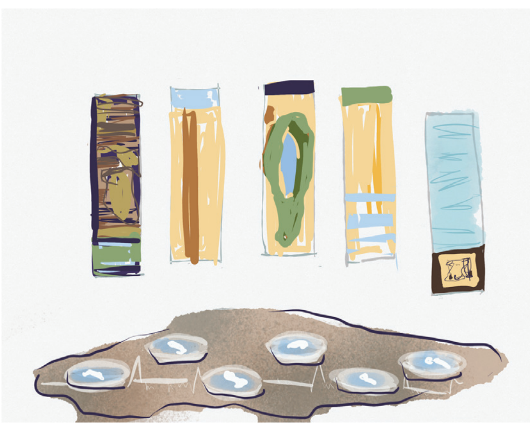

Figure 2. An early thumbnail design considering materials and panel layout.

"Interviews", rather than being either a work of art or a documentation of the science, it is a hybrid, a hybrid that spans both disciplines enabling viewers to cross between a scientific understanding and an emotional involvement, both of which are

Here we present documentation of the artistic process and scientific advancements. The work includes five columns, each section documents the scientific context and imagery upon which the work was built.

From Concept to Physical Design

"Interviews" focuses on progress in our understanding of Greenlend's evolution over the millennia. The columns, defined by updates in methods of studying the ice, are a testament to the ways that diverse data provide complementary insights to the same question, while at the same time illuminating new questions.

The columns highlight the nature of scientific discovery as a continuum rather than a fixed destination. Our knowledge of Greenland's ice sheet and its evolution will continue to evolve as new technologies are developed and additional site work brings new regions into focus. Keisling identified five major developments that increased the depth of understanding of Greenland's ice sheet evolution. Each of these breakthroughs is documented by a column and a corresponding 3D representation of the ice sheet coverage revealed.

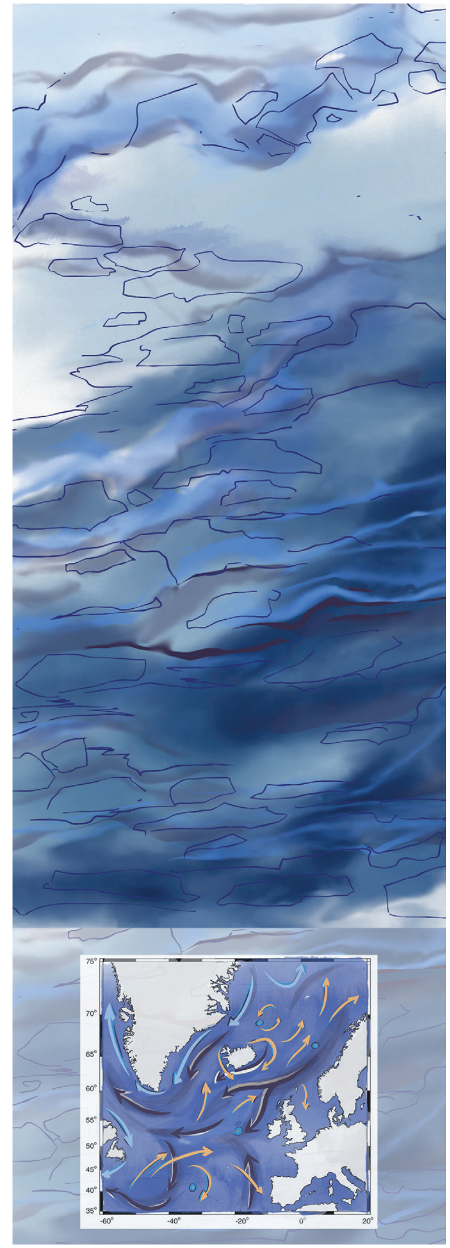

Figure 3. An original panel design on ice shelf layers with a map of the core drilling locations on the continental shelf and the influencing currents.

Physicalization of Ice Sheet Cover in Glass

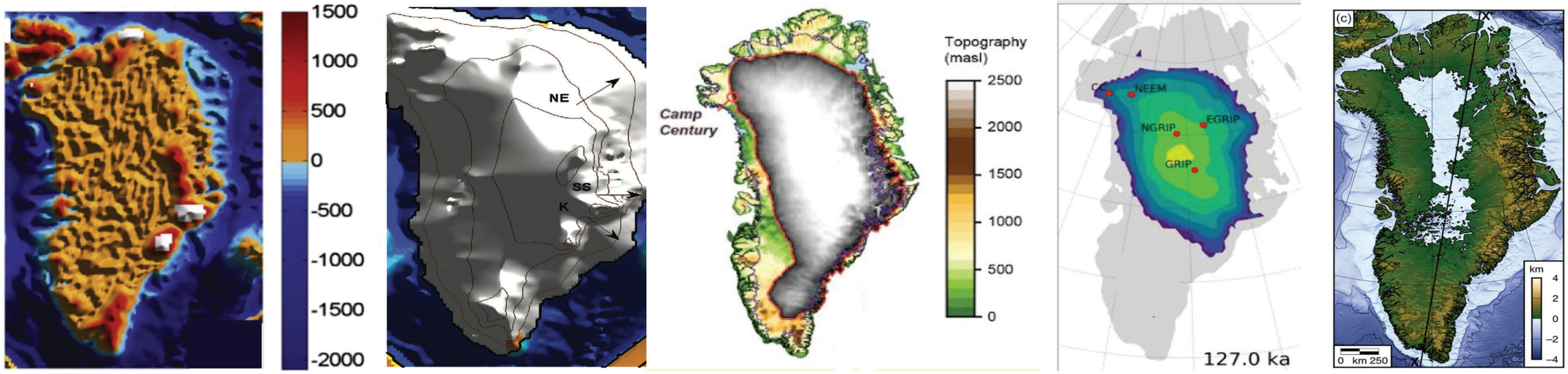

Figure 4. The key information that each datatype considered here has provided is an estimation of the past geometry of the ice sheet on Greenland. Because the ice can take decades to centuries to adjust to a change in its environment, we have to look to the past for clues as to how the ice sheet responded to different conditions. In the process of collecting the data used to create these reconstructions, we often identify new questions, or deepen our existing questions.

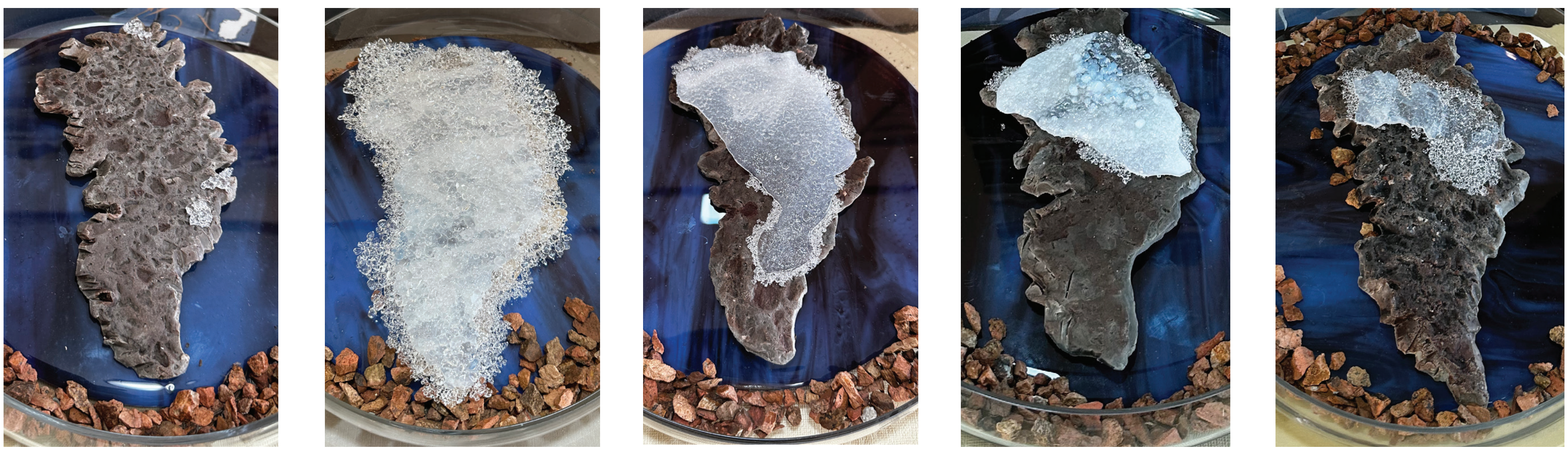

Figure 5. Physicalizations of the ice coverage data in fused glass.

Each bowl contains a cutout of Greenland's bedrock made of clay with a fused glass representation showing the ice sheet coverage as it was understood at that period. Each section is accompanied by a short text explaining the methods of collection and the understanding that the new data provided.

Multiple Dimensions of Thought and Data

Data surrounds all life on planet Earth, and in this age of machine learning, there is no corner untouched by informatic flows. From the smallest nanoparticle to the vast cosmos, we gather data about everything we see, feel, experience, and know. However, data is not only observed externally, but lived experientially through our connection to digital devices, reshaping our embodied experience.

Despite all of the conversations surrounding the changing climate of our planet, internalization of the impending impacts remains elusive. Art is the language societies have used throughout history to address threats too overwhelming to address directly. Here we present work centered on researching the history of Greenland's ice sheet. This work is being undertaken to assist scientists in predicting the rate of ice melt as the climate warms.

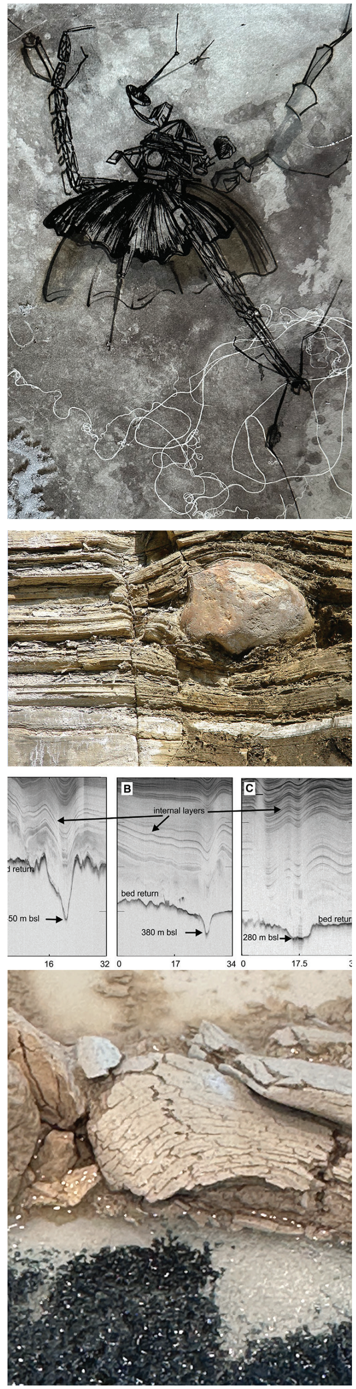

Figure 6 A collage drawn from research imagery: including: an drawing of a satellite; an image of ice-rafted debris from a marine sediment core; a reading of the Greenland's ice sheet from ice penetrating radar; a sculptural relief made from clay and glass.

Our research focuses on identifying means of communicating the current research and factual understanding of the planets' ecosystems and specifically the research underway to better understand and predict what lies ahead in a language that invites entry and an embodied understanding, particularly as it relates to places that are geographically and psychically distant for most people.

Although the ice is often depicted as fragile, the "canary in the coal mine" of climate change, it is also resilient, capable of growing and re-growing when climate cools. Here we present Keisling's current research viewed through the lens of Samsel's artistic practice, tying together the gathering of evidence - the Interviews - with the physical visualizations of our changing understanding of the history of Greenland's ice cover, a landmass that was green not so long ago.

The five columns in "Interviews" represent five points in time where scientists have made leaps in understanding of Greenland's ice sheet history filtered through an artistic lens. They represent knowledge gained through examining marine sediment samples, seismic data of Greenland's continental shelf, drilled ice cores, ice-penetrating radar data and satellite data. Each of these datatypes have particular textures and have been used to reconstruct particular ice geometries in three dimensions, forming our understanding of the evolution of the ice sheet in space and time.

Science is often thought of as an objective truth-seeking process. In reality, the questions scientists ask and how they answer them are subjective and can change and shift in response to new findings and other forces. Just as a deft interviewer must develop new questions over the course of a conversation, so too is science itself altered by what we learn in the process.

Questions and Lessons from Interviewing the Ice

Greenlanders today continue to live around the edges of the great ice sheet, as they have for at least 5,000 years. European and American scientists have observed the morphing ice sheet for the last 100 years.

During that century, we have found clues to the ice sheet's fragility and resilience. Marine sediment cores, offshore seismic data, the ice itself, and the sediment beneath it have told us new stories about the ice. Studying each of these archives has brought us closer to answers, and to a sobering realization: the more we know, the more we don't.

Over the past 100 years, we have been revising our understanding of Greenland as an immovable frozen expanse to that of a dynamic viscous entity, with arteries of fast-flowing ice that carve deep valleys and carry enormous volumes of sediment and nutrients out to the ocean, building and bulldozing an ever-changing landscape.

We now know that in climates not much warmer than today's, the ice sheet shrank, at times dramatically. In climates not much cooler than today's, it grew. This is enough for us to answer one pressing question: without substantial reductions in greenhouse gasses in the future, the ice will melt.

We also have more questions. How quickly will it melt? Which areas will melt first? Will the ocean or the atmosphere cause it to melt faster?

> When it was opened by the giant, the chest gave off a glacial exhalation. Inside there was only an enormous, transparent block with infinite internal needles in which the light of the sunset was broken up into colored stars."
> José Arcadio could only murmur:
> "It's the largest diamond in the world."
> "No," the other countered. "It's ice."
>
> Gabriel García Marquez,
> One Hundred Years of Solitude

We must hold these things together: certainty at the large scale (the ice will get smaller), and uncertainty on the finer scale (when? where? how?). Unfortunately, addressing the latter seems necessary to convince the world that the ice is worth keeping around. So we continue to ask questions.

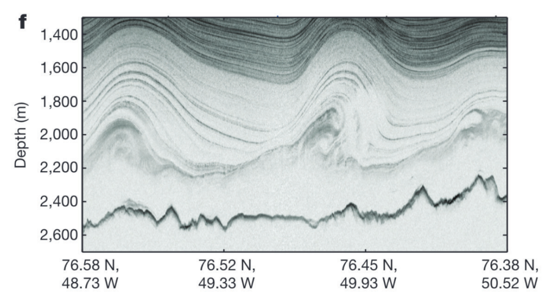

Figure 7. A slice through the morphing ice sheet.

Three million years ago, mammoth and hare roamed the trees [why trees?] at 83 degrees North latitude, enduring the long months of polar night and spending summer days in perpetual sunlight [1]. Perhaps there was already ice, gleaming at the top of the highest peaks. But as Earth's tectonic shifting caused the mountains to rise, and Earth's orbit caused the summers to cool, the ice began to grow so much that it flowed down all the way to the ocean. It carried rocks and pebbles frozen in its body far out to sea in icebergs, where they fell to the seafloor with aplomb, warping the otherwise undisturbed sediments [1]. Around two-and-a-half million years ago, earth's climate cooled further – partially caused by the ice growth itself – causing the ice to grow more. There was now so much ice that it flowed into the warm central lowlands of Greenland and across the continent, hundreds of glaciers coalescing to form the ice sheet. The mammoth and hare fled, as generation by generation the ice sheet covered the once-verdant land, and it did not stop there: eleven times, it grew so big that it advanced hundreds of miles into the ocean on all sides, growing twice as big as it is today [2].
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A few times since then (or perhaps many), the ice sheet got smaller again. The ice knows how to cover its tracks - each time it gets big, it tends to erase evidence of its past behavior as it grinds up rocks in its forward march. But sometimes it misses things.

At the top of the ice sheet today, where the ice below is two miles thick, the very deepest ice contains gasses that are one million years old - the ice has been there a long time [3]. But the ice is not that old everywhere - in many places the ice is warmed by the Earth from below, so that the oldest ice is always being melted. Sediments beneath the ice have their own story to tell – 430 thousand years ago, in northwest Greenland where the ice is a mile thick, the sediments saw the sky [4]. Fossil plants, insects, and rounded river rocks in the sediment tell us this was once a stream flowing across a lush tundra of willow bushes and moss. It might have been fed by meltwater from a nearby ice-sheet, or maybe it was a precipitation-fed stream far from the ice's edge. The sediment tells us that the ice sheet was between twenty and seventy-five percent smaller than it is today.

Motivated by the evidence of upcoming change shown in Figure 5, Interviews documents our evolving understanding of this history within the five columns each drawing on diverse data, representing updates in our understanding.

Above the bottom, the ice keeps track of its own age: like the rings of a tree, layers of ice can be dated, and imaged with x-rays [5]. Ice from a warm "interglacial" period 125,000 years ago has been found throughout Greenland - some of this ice is visible in enormous folding structures, caused by a kind of turbulence as the cold ice from a glacial period shears against the warmer ice below. We know the ice was where (or near where) we image it, but everywhere else that ice has either melted away, or was never there to begin with.

Today, Greenland sheds three hundred gigatons of ice mass per year. This is enough water for all eight billion people on the planet to drink twenty-six gallons each day. The ice sheet is headed towards something that looks like the past. So, which past will be our future?

This depends on, most critically, how much carbon dioxide we force into the atmosphere. And who can predict that? In this way, our knowledge of humanity's future is as uncertain as our knowledge of the ice's past. Some things we know, and some we don't. For our part, we continue to look for clues.
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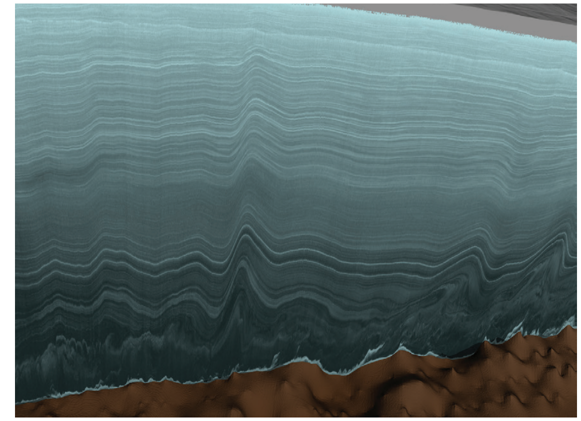
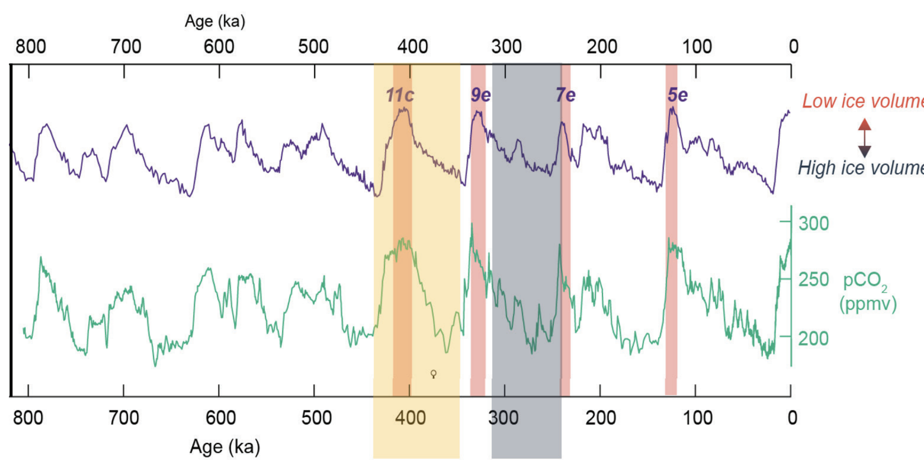
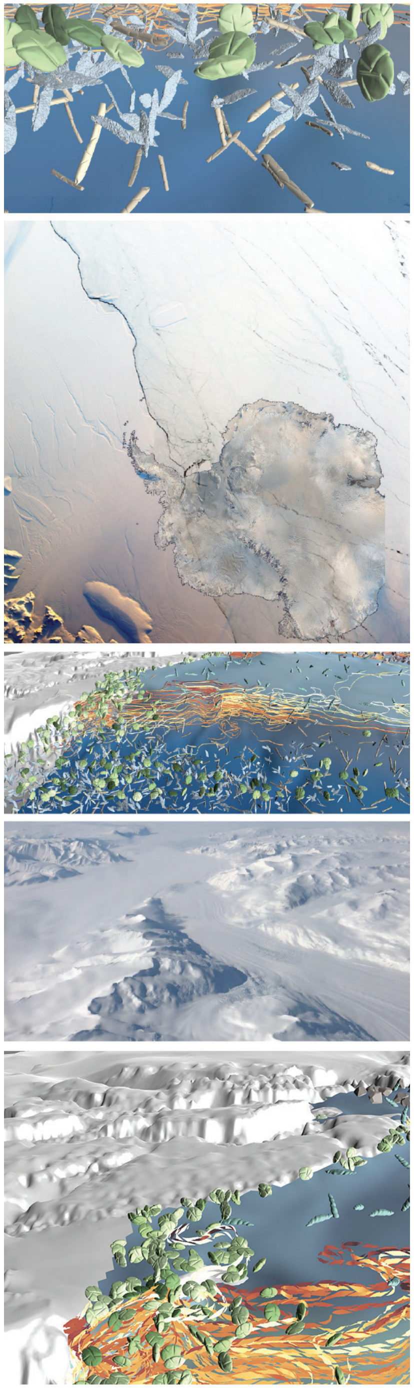


Figure 8. Radar data collected by an airplane flying over the Greenland ice sheet. The lines are layers in the ice with different properties, called isochrones because they represent ice of a single age. The deepest reflectors we can see are up to 130,000 years old, and there is ice up to one million years old near the bed, here shown in brown. Photo: NASA.

Figure 9. (below) The purple line (top) shows the global ice volume, the green line (bottom) indicates the atmospheric carbon dioxide levels. Today we have surpassed 420 parts per million CO2 in the atmosphere, and the ice volume has not yet adjusted to this change [3].





Contextualizing the Fragility and the Reality

Past work has experimented with various means of presenting climate science using scientific visualization that employs a human vocabulary, contextual imagery, physical objects and immersive environments as shown in Figure 10. Figure 10 combines visualizations of ocean water categories under the Filchner Ronne Ice Shelf in Antarctica with contextual imagery meant to connect the data with the actual site.

Figures 10 - 12 illustrate steps in the journey of bring the science to the public with a connection to the physical world, specifically locations of the scientific research.

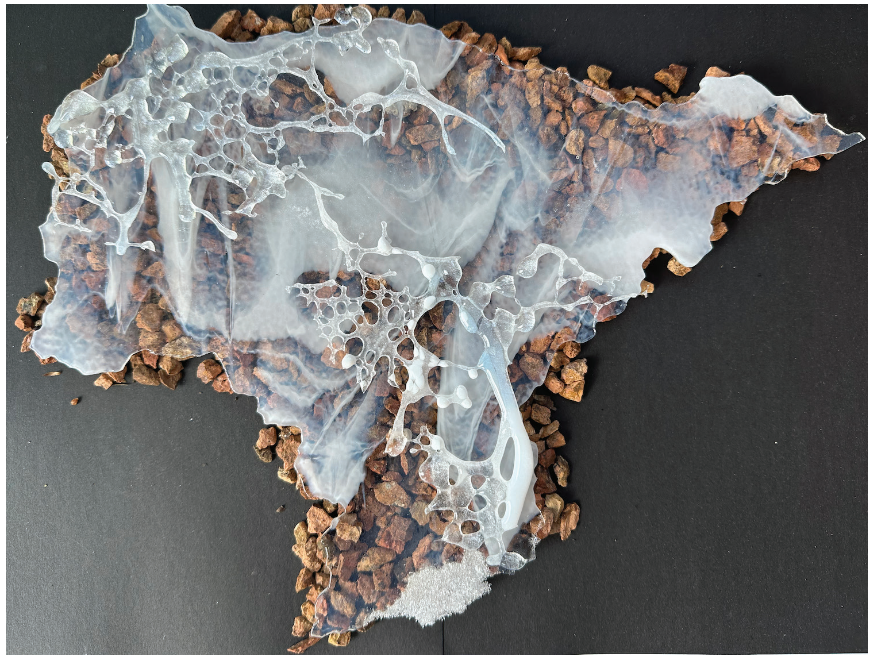


Figure 11 Thwaites, Fused glass and rock of the Antarctic region that drains through the Thwaites Glacier. The glacier is the small granular glass area at the lower right which is holding back the ice flow from this large section of Antarctica.

Figure 10, left, is a digital print of visualizations of the Filchner Ronne Antarctic Ice Shelf, the waters under the ice shelf and contextual imagery on the location.

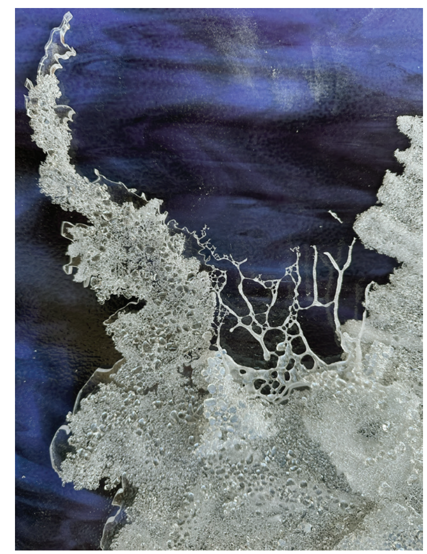


Figure 12 The ice sheet on the Antarctic peninsula and Weddell Sea metaphori. cally represented in fused glass.

Column One: Marine Seeds

The Kap København formation was described by Danish scientists in the early twentieth century. The sequence consists of multiple glacial tills sandwiched between shallow marine and terrestrial sediments documenting one or more phases of ice-sheet retreat early in the ice sheet's history. Studies on DNA preserved in the sediments have shown a rich. And varied ecosystem including willow, larch, mammoth and hare. The formation has been dated to 3.1 million years ago, based on a combination of paleomagnetism and amino acid racemization. Prior to this time, two phases of mountain-building, caused by tectonism and upwelling in the mantle, raised the landscape in southeast Greenland enough to permit glaciation (Solgaard et al. 2013). Glaciers grew first at the peaks, as shown in Figure 12, and then expanded to sea level, where they calved off icebergs laden with rocks eroded from the ice sheet's bed.

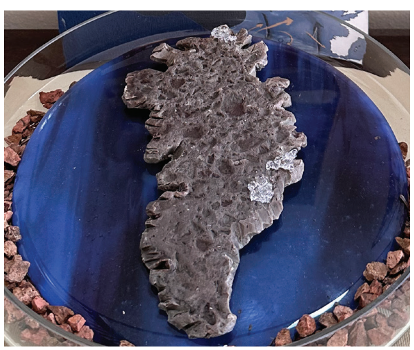


Figure 15. (left) The physicalization of the ice sheet coverage in ceramic and fused glass.

Figure 13. Dropstones/ice-rafted debris in marine sediment cores off East Greenland.

These rocks, commonly termed "ice-rafted debris," appear infrequently in marine sediment cores off Greenland's coast as early as six million years ago (Jansen et al. 1991) but increase in frequency and magnitude 2.7 million years ago, probably associated with a major advance of the ice sheet throughout Greenland and the deposition of one of the overlying till units at Kap København.

Interview Findings

A key observation is that these larger stones, shown in Figure 13, disturb the layers of sediment beneath and above them. They are deposited by melting out of icebergs far from shore.

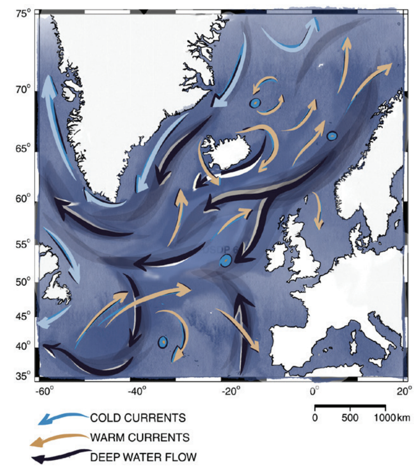


Figure 14. A map of the currents and locations where the samples were extracted.

Column Two: Sediments

On the continental shelf off West Greenland, oil and gas companies have imaged the subsurface using seismic techniques, hunting for resources. Sound waves released from a ship, often created by releasing pulses of compressed air, propagate through the water and into the sediments below and reflect off variations in density. These reflections, measured by a long string of microphones towed behind the ship, can be used to reconstruct a picture of the subsurface. By doing this many times, and in different directions, a three-dimensional map of the world beneath the seafloor can be constructed. Data of this quality and density are expensive and difficult to collect for science alone, but sometimes companies are inclined to share their data with scientists, as is the case here. The seismic reflections off West Greenland reveal eleven distinct sediment packages, created by the ice sheet during periods when it grew even larger than it is today (Knutz et al. 2019). Because the ice sheet reaches the coast around much of the island, in order to grow bigger the ice must advance into the ocean, an environment which is hostile to ice growth.

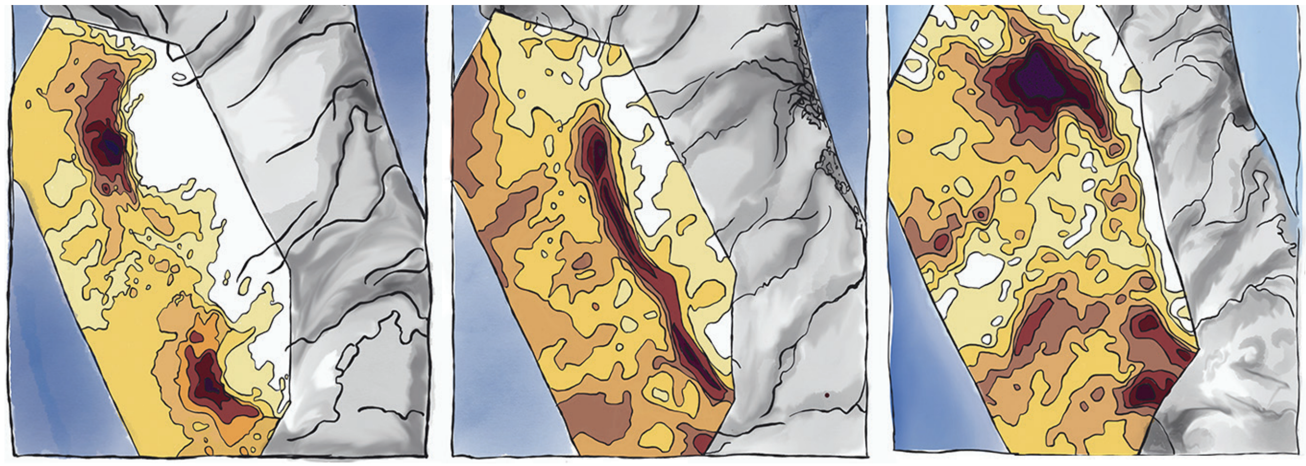


Figure 17. These images show the changes in sediment thickness at different times in the past, from 2.7 million years ago (furthest to the right), 1.5 million years ago (center) and 21 thousand years ago (left). Dark colors correspond to more sediment being deposited by the ice sheet at its edge. The variations from two centers of deposition, to one, and back to two suggests a change in the dynamics of the ice flow in response to the changes in topography that the ice sheet itself has created. (Knutz et al. 2019) #

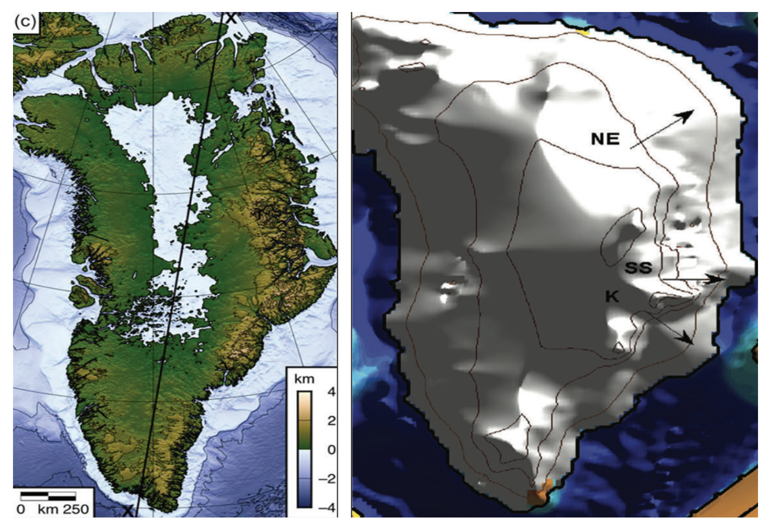


Figure 18. A model of Greenland ice cover when the the ice advances out to the edge of the continental shelf (right), as suggested by the seismic data. The weight of the ice causes the bedrock beneath the ice sheet to sink (left), causing large parts of interior Greenland to be pushed below sea level. (Funder et al. 2011, Knutz et al. 2019)

Column Two: Sediments

The illustrations in Figure 17 and in the upper section of Figure 21 show sediments brought to the coast by the ice sheet as it advances change the topography of the seafloor, making it shallower, gradually allowing the ice-sheet to grow further and further out with each successive advance. Although not yet individually dated, the eleven sediment packages mapped here were deposited between 2.7 million years ago (the oldest) and 21,000 years ago (the youngest), the most recent time that the ice-sheet advanced out into the ocean (Funder et al. 2011).

Physicalization of the data is a critical elements of the work, bring reference to the physical world by incorporating the physicality. Our experience has shown that viewers are drawn to the natural materials of clay and glass and readily identify those materials as being of the earth.

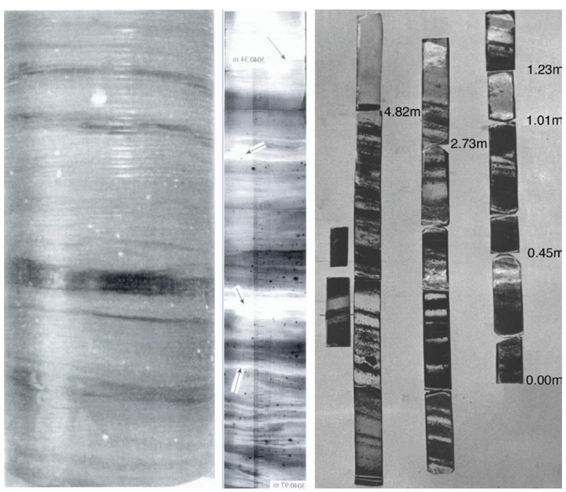
Figure 19 shows the combination of the collage panel with the related ice sheet cover. Figure 20 shows the ice sheet cover from the periods of Columns One to Three, illustrating the radical changes in Greenland's ice sheet over time.

Figure 21. (right) the collage section of Column Two with images of the sediment brought to the coast in three different time periods.

Figure 20. (below) Greenland's bedrock and ice sheet coverage from Columns One to Three, in fused glass and clay.

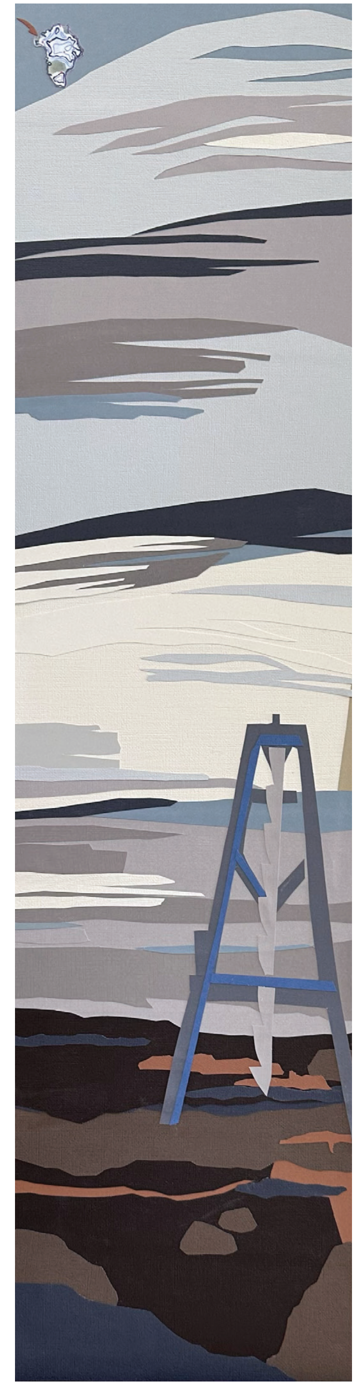
Figure 22 Century site drilling equipment.

Figure 23. Ice core samples.



Column Three: Century Drilled Ice Cores

Deep ice cores have been collected since the 1960s, and have led to many important discoveries about the properties of ice and especially changes in Earth’s climate. For the latter, it is important that the ice be stratigraphically continuous, meaning that the age of ice changes in a linear and predictably way as a function of depth. This is the case for most of the ice-sheet, except for very close to the bed itself, where it has long been recognized that the ice is disturbed and distorted, mixed with sediments and pebbles entrained from below. In some places, deep ice coring missions have also retrieved subglacial rocks or sediment. Long ignored and in some cases forgotten or misplaced, these subglacial sediments and dirty basal ice are now playing a key role in reshaping our understanding of ice-sheet history as our analytical techniques have advanced. In 2016, rocks collected from beneath GISP2 in 1990 were analyzed using cosmogenic nuclide techniques, demonstrating that the ice sheet has been much smaller than it is today at least once during the last 1.1 million years, and perhaps may times. In 2021, sediments collected beneath Camp Century in 1966 were analyzed using optically-stimulated luminescence dating, showing that this area of northwest Greenland was ice-free as recently as 430 thousand years ago. The dirty, stratigraphically incoherent basal ice has already yielded some clues to ice-sheet history – at Dye-3, the oldest ice is also 430 thousand years old, and at GISP2 the oldest ice is about one million years old (Yau et al. 2016). Now, an international team of scientists is tackling the question of basal ice in a concerted and coordinated effort, to see what secrets this enigmatic ice has yet to teach us.



Column Four - Deep Radar Reflections
125,000 years ago Earth experienced a natural period of warmth that lasted around 10,000 years, driven by changes in our orbit relative to the sun. Although it was much warmer (up to +8ºC) in parts of Greenland, we know that the ice sheet did not completely melt away because ice that is at least this old is found near the bed throughout the ice sheet (NEEM, Community Members 2013). Ice-penetrating radar, mounted on airplanes, has been used to measure the internal stratigraphy of the ice sheet in great detail. Changes in the concentration of impurities in the ice, like dust and sea salt, lead to changes in conductivity that the radar waves reflect off of, allowing us to image layers in the ice sheet called isochrones, so-called because they represent the surface of the ice sheet at a particular moment in the past, now distorted by thousands of years of ice-flow (Keisling et al. 2014). Although the layer from this past warm period 125,000 years has been greatly deformed, it is distributed throughout Greenland, helping us to place constraints on the maximum amount of ice lost from Greenland during this time (Plach et al. 2018). The radar data also led to the discovery of ice folds up to a kilometer in height that seem to emanate from the bed.

Figure 24. Panel Four references the slice through the ice able to be generated from the ice-penetrating radar, as well our understanding of ice coverage and a reference to the ice melting at the bottom of the ice sheet, being heated from earth's core.

Efforts to reproduce this behavior in models of ice flow led to the discovery that these folds are caused by the different material properties of ice from this past warm period, relative to the cold "glacial" period ice that sits above it (Rathmann & Lilien 2022). The warmer ice is more resistant to deformation because it has fewer impurities, whereas the glacial ice is full of dust that causes it to flow quickly. Where these bodies of ice meet, the deepest ice buckles and shears, creating the large structures that we observe in radar data throughout Greenland (Panton and Karlsson 2015).

Figure 25. (right) Estimates from different models showing the smallest ice extent achieved during the Eemian Period 130kn to 118 ka.

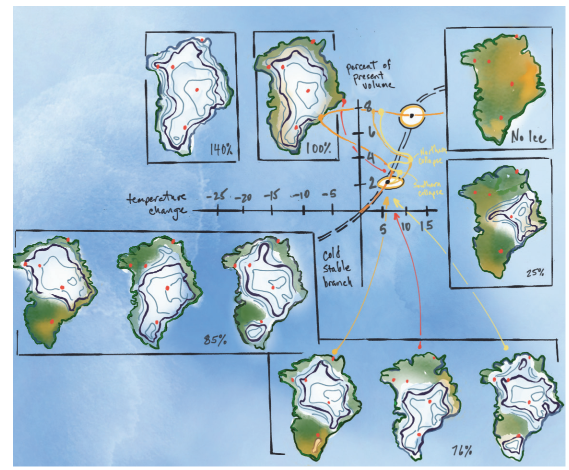
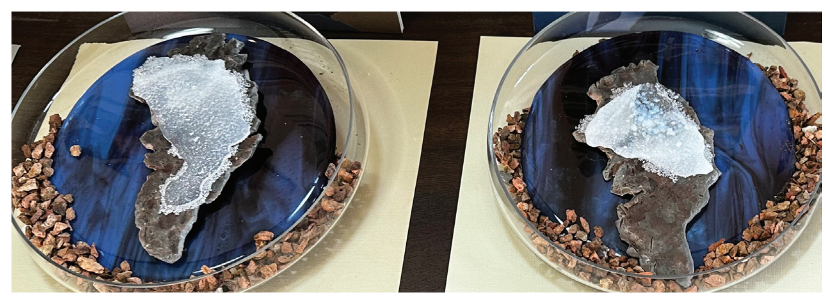


Figure 26. (below) Physicalization of the ice sheet coverage from Columns Three and Four.



Column Five: Satellite readings, Land Ice Mass Loss, and Sea-level Rise

Column Five speaks of the data collected over the years by satellites which has enabled us to watch the changing ice levels on Greenland. The concern is the vast quantity of water rapidly melting, specifically, the impact and threat that meltwater poses to coastal communities around the globe and to the global ocean conveyor that is disrupted by the fresh water from the glaciers. The five Greenland maps (visualization by NASA) in Figure 28 show the increasing levels of land ice melt loss from 2002 to 2023.

Figure 27. The ice sheet and bedrock from Column Five.

For as long as we have been observing the Greenland ice sheet from space, it has been melting. Unequivocal measurements of ice-sheet mass change come from the GRACE (Gravity Recovery and Climate Experiment) satellites. GRACE is a pair of satellites that orbit the earth together, continually measuring their distance from one another using an extremely precise laser. As the satellites pass over Earth, fluctuations in the strength of the gravitational field cause the leading satellite to accelerate or decelerate, leading to a measurable change in the distance between the satellites, thus permitting the reconstruction of small changes in Earth's gravitational field over time. The satellites are so precise that they are also able to measure the fluctuations in gravity over the course of each year, as snow falls and accumulates in the winter and melts in the summer. Since the launch of the mission in 2002, the satellites have measured a year-over-year decrease in gravity directly over Greenland, associated with the melting of ice and loss of mass from the ice sheet that is not balanced by winter snowfall. Over this time period the ice sheet has lost approximately 300 Gigatons of ice per year, and there are signs that this loss is accelerating (Copernicus 2021).

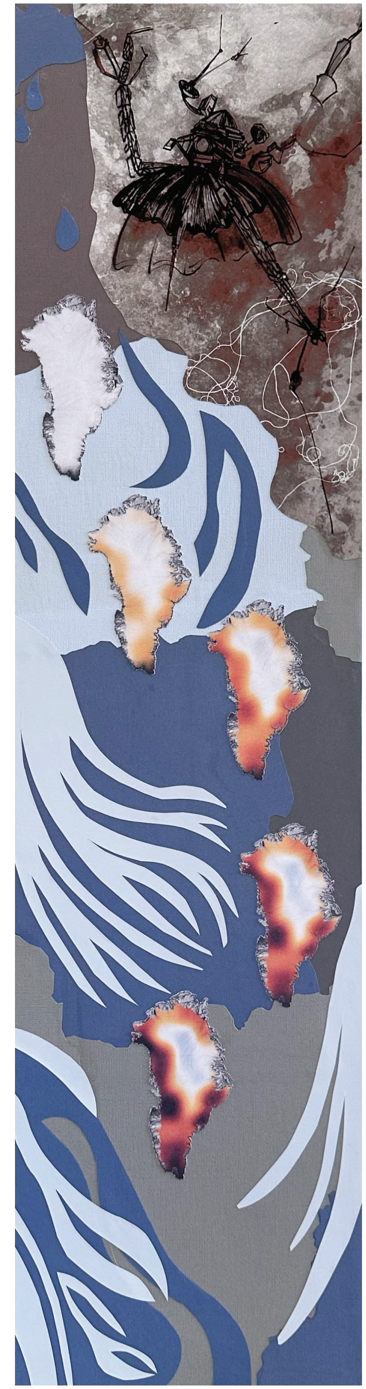


Figure 28. The Collage section of Column Five containing: an copper plate etching of an early satellite; a visualization of Greenland's ice melt rate from 2002 to 2023; and reference to the changes in the ocean conveyor belt due to the influx of fresh water as well as sea level rise.

Interviews

The panels, explained in the previous text, are accompanied by data physicalizations of the ice levels on Greenland that were added to our understanding via the methods documented in their accompanying panel. The purpose was to show not just the rapidly melting ice but the science and effort that is undertaken to gain an understanding of the ice history so that we can better predict the future. Like all scientific inquiry, our understanding is constantly evolving, refining knowledge of our complex interactive earth systems. .

Figure 29. Interviews, an installation by Francesca Samsel and Benjamin Keisling about the research underway to understand Greenland's ice sheet history and what that can tell us about its future and ours.

Conclusion

Many organizations and institutions acknowledge the value of supporting and presenting work that speaks of environmental change via the language of art. But the practice has a long history.

In 1959, right around the time scientists were collecting the first cores from Greenland's continental shelf, C.P. Snow gave a lecture on the split between the sciences and the humanities (primarily literature) and how both were needed to address society's needs and solve the societal problems. Much has been written since including expanding the humanities to include all the visual arts, music and more.

Interviews is designed as a bridge between people and environmental changes in a far away place.
By reflecting the environments, from their enormity to the detail of textures and means of data collection that scientists encounter in the course of their work, we seek to bridge the gulf between scientific knowledge and an embodied understanding of Greenland's history, and by extension, its future.

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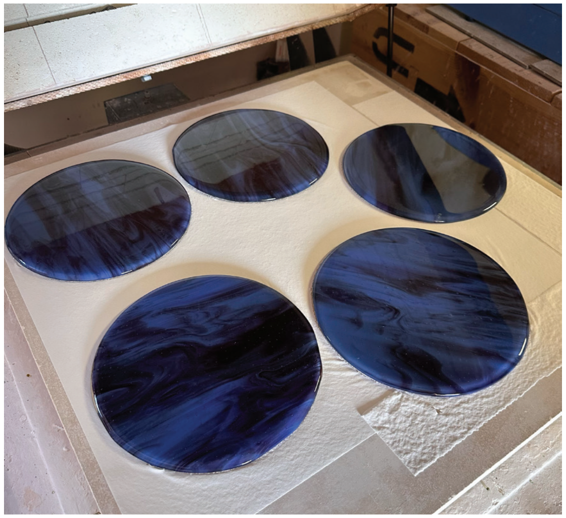

Figure 30. The glass disks representing the ocean coming out of the fusing kiln.

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Future Work

Figure 31. On the drawing board are explorations created from earthen materials, glass, clay, gravel, sand and more. Materials drawn directly from the earth speak clearly to the beauty and the wonder of our planet bring the far away, closer to our daily lives.