

Eleven Movements of the Cryoscape - Ecological Explorations in Sonification for Affectively Engaging with Climate Change

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Abstract

In this paper we present the sound installation *Eleven Movements of the Cryoscape* which was created for the new Kangiata Illorsua – Ilulissat Icefjord Centre in Greenland. The installation is a near real-time sonification of the movement and melting of the Inland Ice, consisting of an array of eleven speakers, each transmitting from a different location in Greenland. The installation portrays the Inland Ice as a living, breathing, evolving organism in the age of the anthropocene, where humankind has made its mark on the very changes that occur to the natural sounds over time. The installation invites people into an affectively engaging and contemplative relation to our changing ecologies through sonification of data to reflect on our present condition and to potentially imagine and connect to new realities. In this paper, we present the process leading to the creation of the installation and how it adds to existing research into sonification and listening practices in artistic and design research.

Keywords

Sonification, Climate Change, Ecological Data, Cryoscape, Listening, Affective engagement, Artistic Research.

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Introduction

The Inland Ice plays a key role in the global climate change debate. Accelerating melting of the Inland Ice is one of the problems we have been facing for a long time in a world, it seems, in perpetual ecological and technoscientific crisis.^{13,18,21,57,59} There is a paradox between the hopelessness and apathy many of us feel, and questions of how things could be different, an urge for change and action (e.g.,²⁷). In the following paper, we present a sound-driven artistic intervention that might contribute to altering affective attachments and mobilizing climate action through listening and attuning to the geological movements of the Inland Ice.

Eleven Movements of the Cryoscape is a near real-time stream of sonification of seismic data and wind data, from the GLISN network of seismic sensors¹⁹ and PROMICE weather stations [⁴², see Fig. 5 and 6], normally used for scientific monitoring of the Inland Ice. The installation is situated at the Ilulissat Icefjord Centre, Greenland and consists of an array of eleven speakers, each transmitting from a different location in Greenland. Sonifications of seismic signals—movements of waves that travel through the earth and ice from the ice sheet, sea ice, ocean tides, ice streams, icebergs, calving fronts, and glaciers—are transmitted, allowing visitors to listen beyond the range of the human ear. The soundscape consists of ice, wind, waves, earthquakes, and human activity on the island from the past week. The installation plays back a 15-minute loop that is updated every night at midnight. The wind speed at each of the locations controls the volume of each seismic transmission to highlight how multiple environmental factors are interconnected in relation to ice as a body of knowledge, towards identification of climate change. The installation portrays the Inland Ice as a living, breathing, evolving organism in the age of the Anthropocene, where human beings have made their sonic mark on the natural soundscapes. Today, human involvement can be heard beyond what acoustic ecologists refer to as the anthrophony, i.e., the "human-made sounds."⁴⁰ We are not just listening to ice with a touch of human presence. We are listening to ice as it is radically altered by humankind.

In the installation, climate changes and the melting of the Inland Ice is expressed as an ever-changing orchestration in what we rather than a soundscape have chosen to refer to as a "cryoscape" understood as an ecocritical framework to emphasize the dynamic relationship between ice and people. In so doing, we follow the work of Carey et al. who look at glaciers within a feminist framework, for global environmental

change research.³ Art historian Isabelle Gapp positions glaciology in an eco-critical art history.¹⁵ The term cryosphere, first introduced by Antoni Bolesław Dobrowolski to describe the frozen-water parts of the Earth,⁹ has resulted in several subsequent typologies that draw upon ice and snow between culture and environment. The idea and term *cryoscape* was first used by Marcus Nüsser and Ravi Baghel to consider glaciers as more than physical landscapes and accounts for glaciers within epistemic, social, and cultural practices.³⁶ Sverker Sörlin looks to *cryo-history* to denote the historical role of humans in determining the fate of ice in the Anthropocene.¹⁰ Isabelle Gapp, furthermore, points to how Elizabeth Leane suggests the term *cryo-narratives* as a reference point for broader and more discursive studies surrounding the cultural history of ice³² and how Klaus Dodds and Sörlin position such multidisciplinary discussions within the new field of *ice humanities*.¹⁰ This positions ice as a core part of *environmental humanities*—the study of how our ideas about the more-than-human world, aka "nature" in literature, film, art, and other cultural practices shape how we relate to it materially and politically and how ice gets experienced, represented and storied.

Methodologically, the project has been carried out as practice-based research⁵ and research-creation⁶⁰ combining artistic practice with theoretical concepts to produce new knowledge. The project extends ongoing inquiry into sound and sonification (e.g.,^{26, 35, 47, 49, 50, 51, 54}) and engages with a range of data sonification/sonic methodologies^{1, 11, 65} within a sonic materialist^{61, 62, 63} and affect theoretical perspective^{34, 14, 13}. With this installation, we would like to extend existing investigations into sonifications as negotiations between aesthetics, politics of mapping and data representation (art, science & technology). We argue that data sonification can lead to affectively engaging and sonically sensible spaces for listening to "mute," invisible or inaudible ecologies, allowing us to "open our eyes" for a minute, by opening our ears—in which there are infinite possibilities for transformative experiences and ways to connect, interpret, understand and "invent" those ecologies. The article is outlined in the following way: We first position the work with the installation in relation to existing work on data sonification and artistic engagements with climate-oriented sonic installation design. We then present in-depth the work leading to the installation and the guiding research questions that have been explored through the creative process. This leads to a presentation and analysis of the installation in light of said questions and related to lines of inquiry at the intersection between climate change, ecological data

sonification, listening practices, art, science and digital technology. Following this, we discuss the knowledge contribution of the work in and outline future explorations in the transdisciplinary and transitional encounter between art, design, and technology towards rekindling affective attachments for imagining a more livable future.



Figure 1. Permanent installation at Kangiata Illorsua – Ilulissat Icefjord Centre; *Eleven Movements of the Cryoscape* transmits near real-time seismic data as sound, from eleven locations in Greenland. Source: Louise Foo (2022)

Sonifying Ecological Data

In this section we position our work in relation to existing literature and projects within scientific data sonification, in particular seismic/glacial data sonification. In addition, we add perspectives on listening as a form of affectively engaged ecological attunement to more-than human aspects of the Anthropocene in a time characterized by climate change.

Data Sonification in Science, Music and Art

Sonification of data has most extensively been utilized for scientific purposes, but also, as a means for musical composition^{56, 65} and as an expressive medium in art installations. In the article *Sonifying the World* authors Kanngieser and Gibb point out how human ears are sometimes better than our eyes at detecting subtle changes over time and that sonification—understood as the turning of data into sounds—has emerged as an increasingly popular practice in recent years. In 2016 Scientists succeeded in proving Einstein's general theory of relativity by listening to gravitational waves: "Finally astronomy grew ears. We never had ears before."²⁹ In musical sonifications composers will typically map data to musical elements such as pitch, rhythm, and timbre. There are several examples of compositions where climate data has been translated to music in one way or the other, to emphasize climatic changes. e.g., "The Climate Symphony and Other Sonifications of Ice Core, Radar, DNA, Seismic and Solar Wind Data"—a one-hour performance/presentation of

sonification research by Marty Quinn of Design Rhythmics Sonification Research Lab⁴⁹ Kanngieser and Gibb point out, how compared to the noisy nature of ecological data, many categorized as musical sonifications, feel strikingly composed, with the use of familiar western scales, "carefully curated for listening ears."²⁵

Eleven Movements of the Cryoscape contributes to this transdisciplinary field through inquiry into the use of near real-time streaming in sound art installation. The artist and writer, Andrea Polli, has contributed notable works in sonification as sound installations exemplified in works such as her documentation of arctic melt⁴⁸. Rather than having to rely on data models and projections like Polli, today, due to rapid technological developments that allow us to live-stream geo-data sent via satellite by the hour from various glaciers around the Arctic, we can explore new artistic potentials and narratives of immediate, immersive, and real-time character. An example of the use of near real-time seismic data in sonification is Herald/harbinger By Ben Rubin and Jer Thorp—which is framed as "a long-distance conversation between a glacier and a city." The artwork monitors the rumblings, cracks and shifts of the moving ice and transmits seismic data to control sound/lights at an installation at a building in Calgary.⁵⁵ Similarly, to this project, *Eleven Movements of the Cryoscape* utilizes seismic data, but from several data sources rather than from one. While the artist behind *Eleven Movements of the Cryoscape* initially set out to compose a soundscape like is the case with *Herald/Harbinger*, through collaborative efforts and prototyping it became clear that the raw data offered an "authentic" aesthetics emphasizing the sense of "tuning in."⁶¹

Listening to Ice

Scientists are increasingly using sound as a crucial element in climate research. Dr. Evgeny Podolskiy, professor at the Arctic Research Center at Hokkaido University in Sapporo, Japan states how "Glaciologists just opened their eyes to studying glaciers about 150 years ago. We started to look at glaciers from different angles, perspectives, satellites—but we forgot to open our ears."⁴¹ In *Geophysical Research Letters*, Podolsky writes about sounds he has recorded, not with expensive geophysical sensors, but with a smartphone in Bowdoin Glacier (Kangerluarsuup Sermia), located in northwestern Greenland. His recordings captured a unique sound which he used to describe a specific drainage process within the glacier—one that is

impossible to observe from the surface: Meltwater drainage through a crevasse. "I've been studying glacier geophysics for quite some time and I found that there is this kind of natural zoo, or a universe, of sounds which we kind of totally ignored until recently."⁵²

Oceanographer Oscar Glowaki's work with Cryoacoustics—the study of ice through noise involves listening to the air bubbles from glacial ice.¹⁶ 1000- year-old ice does not just contain information about snow, temperature, and pollution, but it also has an interesting sound. The bubbles contain 1000 years of atmospheric air. When melting glacial ice in water, the bubbles explode due to the pressure of a series of small micro-explosions: Each bubble sings (click-click-click) and that is how glaciers produce what Glowaki refers to as the loudest sound in ocean acoustics. He points out how satellites from space can be used to track the melting of glaciers or icebergs. But what is much harder to get data from is that spot where glaciers meet ocean water—and that ice-ocean boundary is where a big part of the melting occurs.⁸

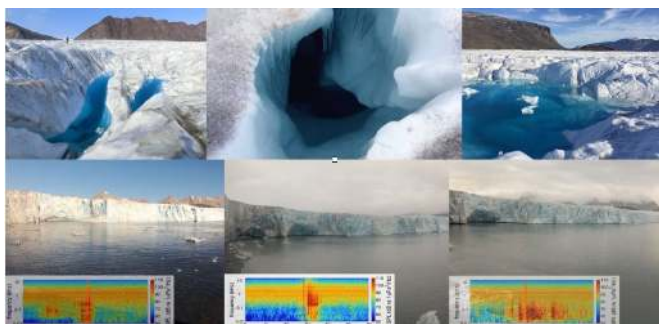


Figure 2: ABOVE: After many years in the field as a glaciologist, Podolskiy found that different types of glacial environments produce their own unique soundscapes. *Source: Article in GlacierHub – Ramming / Evgeny Podolskiy (2020)* BELOW: Underwater acoustic signatures of glacier calving. From left: 1: Typical Subaerial event. 2: Sliding Subaerial event. 3: Submarine Event. *Source: Oskar Glowacki (2015)*

In geophysics, sonification has been used to understand long-range and large-scale seismic events, such as earthquakes and volcanoes⁴⁴ and is increasingly utilized in the study of glacial data. Throughout our research we have come across audio examples of seismic data converted to sound and found it fascinating, considering how seismic data is very similar to sound—vibrations of waves that propagate through the earth, rather than air. And if you speed up the data, you can listen to it. It turned out that raw seismic data, already converted to sound, is available from an extensive network of sensors monitoring Greenland through the GLISN Project in near real time. The main goal of the project is to “provide real-time data from sensors in and around Greenland for detecting, locating and characterizing glacial earthquakes and other cryo-seismic phenomena, and to

contribute to our understanding of Ice Sheet dynamics.”¹⁹ Scientists do in this regard look and listen for very specific glacial events, and will exclude data that in the ears of science is “irrelevant,” but perhaps this data could be relevant to listening ears within artistic contexts? Hence, we became curious to listen to the sonic phenomena and the going on, in addition to what was flagged as earthquakes and the 3-4 daily major glacial events (icebergs calving and ice quakes), and we began listening to ongoing constant streams of seismic data from the GLISN network.

Affectively Engaging with Sonified Ecological Data

Eleven Movements of the Cryoscape presents us with an opportunity to listen to otherwise mute ecologies, by simply “tuning in” on them; making those ecologies perform on their own. It asks if we, through aesthetic and affective experiences and through sonic sensibilities of listening⁶¹ to “mute,” invisible or inaudible ecologies can ‘open our eyes’ for a minute, by opening our ears. Salomé Voegelin, an artist, researcher, and writer engaged in listening as a political practice, emphasizes the role art and sonic practices play in asking relevant and necessary questions on today’s global challenges such as climate change. Voegelin articulates how there are sonic potentialities, sensibilities, and competencies^{61, 62, 63} yet to be explored. In her most recent volume “Fragments of Listening: Political Possibilities of sound”⁶³ she emphasizes how there is a need for explorations in interdisciplinary domains, in a time where “ecological questions need answers from unknown places”⁶³ Voegelin describes listening as an interactivity that challenges, augments, and expands what we see, without presenting an additional illusion to the scene, but by producing the reality of lived experience as invented spaces, not unreal, but phantasmagoric. Listening does in this sense not enhance those environments—it produces them. Voegelin, furthermore, articulates how “duration” and “real-time” qualities produce “not a sense of listening to, but listening in.” The “listening in” and “sense of real-time” produce “authenticity.”⁶ Kanngieser & Gibb point out how sound influences the way we know the world; and whether intended or not affect and emotion intervene when sound is used in novel ways such as sonification.²⁵ Affect is understood as an in-between, pre-personal, relational, and more-than-human concept whose intensity ultimately colours our engagement with ourselves, each other, and the world.^{14, 34} Fritsch has emphasized the role of affect in situations of

catastrophe and crisis “at the end of the world,” advocating for an exploration of the role of digital technologies to create positive changes in affective attachments on an ecological scale.¹³ For this relational change to take place, there needs to be a form of affective engagement¹² occurring at an infra-individual level between human and non-human bodies—of flesh, of ice, of sound. Affective engagement in the case of *Eleven Movements in the Cryoscape* thus describes the potential for a really felt impact that might cause people to act or feel differently by being “taken into” the sonified movement of the ice.

Creating Eleven Movements of the Cryoscape

In this section we will present the process of inquiry leading to the construction of the final installation of Eleven Movements of the Cryoscape. Our main intention is to both foreground the creative and artistic process as a form of listening, while at the same time foregrounding the forms of listening emerging for a broad range of stakeholders during the process. Doing so, we will contribute with insights concerning the (listening) work required in processes concerned with artistic explorations of scientific, ecological data to create an affectively engaging sonification that can open a sensory and contemplative space for attuning to the inland ice in the light of climate change in the Anthropocene.

Context of the Collaboration

In the summer of 2021, Ilulissat Icefjord Centre, designed by Dorthe Mandrup, opened by the icefjord in Ilulissat in Greenland. The Icefjord Centre is run as a self-governing institution, and is built by a partnership consisting of the Greenland Self-Government, Avannaata Kommunia and the philanthropic foundation Realdania who in the following quote state one of the projects key missions: “With its unique location on the front line of climate change, the new Kangiata Illorsua – Ilulissat Icefjord Centre will play an important role in conveying the effect of climate change on the ice sheet.” (Jesper Nygård, CEO of Realdania). JAC Studios was responsible for exhibition design and curation of the exhibition, which disseminates knowledge about Greenland's geological, biological, cultural, and climatic history. The exhibition consists of a permanent exhibition with cinema, central exhibition space, and lastly a separate

exhibition space with the working title “Future Lab.” For this part of the installation, artist Louise Foo and photographer Anna Domnick were invited to each create a new artistic work based on scientific climate research. Several meetings were held between JAC studios and the artists in which there were brainstorming and sharing ideas, knowledge, and research. A workbook was developed through these sessions, with the following incentives: To give a 1:1 experience of climate. For audiences to experience the inland ice through the senses, sound should be the emphasis, an immersive experience that shows the “unseen” parts of the icefjord, reflecting the spectrum of ice through an instrument—possibly using real-time ice recordings to give live feedback of the current condition and research on the inland ice in an installation that focuses on reflection—reflecting on the place of your own body, your influence on the Icefjord, the influence of the icefjord on you (to reflect on how the Greenland ice sheet influences the global condition) JAC also initiated a workshop / meeting between the artists and scientists from Niels Bohr Institute³⁷ and GEUS (geological survey of Denmark and Greenland).¹⁷



Figure 3: Kangiata Illorsua – Ilulissat Icefjord Centre. 2021. Designed by Dorthe Mandrup. Source: Adam Mørk (2021)

Listening & inquiring: from field recordings to **sonic fields**

To begin with, the process of inquiry took its point of departure in focusing on surface melt and glaciers calving, which are some of the major contributors to ice sheet mass loss. Initially, the artist set out to build an archive of recordings of melting ice & recordings of calving glaciers to facilitate the soundscape. The artist was inspired by Jakob Kierkegaards sound installation *Isfald* in which he uses equipment that gives us opportunities to listen to sounds that we usually cannot hear; underwater with hydrophones or surface transducers to record vibrations of the earth [30] and

was planning to do her own sound recordings in Greenland in the summer 2020 while also exploring options of collecting sound from other artists and scientists. The artist navigated sonic phenomena of ice of the arctic through readings, listening to sound files and through contacting a handful of experts (J. P. Steffensen, Glaciologist Andreas Ahlstrøm, Seismologist Peter Voss, Oceanographer Oscar Glowaki, Sound recordist Simon Forrester) who hold recordings of ice and glaciers from across Greenland – both from above and below the water. Obviously, the natural soundscape of ice will be quite different depending on where in Greenland you place your ear or microphone. If a person is standing in the middle of the Inland Ice for example, there is almost no sound, except for the occasional sonic phenomena of ‘firn-stoss’—a collapse of snow (about 5 cm) that happens due to changes in temperature, that can spread several miles, sounding like a rumbling thunder. The artist was fascinated with the complex palettes of sounds of ice and the qualities inherent in movements caused by temperature changes and the sonic states of frozen to liquid in various scales, from microscopic ice crystals crackling, to dispersion of sound waves in ice sheets, to singing, frozen lakes, to rumbling devastating noises of calving events and she became curious to get access to the inaccessible sounds, e.g. sounds to be listened to, beyond the human hearing range. After having listened extensively to various sonic representations of glacial ice in the form of field recordings and data samples (presented throughout this article and see Figure 4) the artist found it problematic that some of the ice sounds would be very pleasing to the ear (when in fact what audiences are listening to is a world in crisis) or on the other hand sounds of calving events or ocean noise were so noisy and overwhelming that she was afraid it would scare audiences away—although that can indeed be a strategy in itself.

Polli’s 2004 work *Heat and the Heartbeat of the City* is an example of a piece that is not an easy listen, as it plays on discomfort and danger.⁴⁵ Kanngieser and Gibb point out parallels in Polli’s work to work in Soundscape ecology and field recordings e.g., recordings of the melting glacier “Vatnajökull” by Chris Watson⁶⁴ or Krause²⁸ who has returned to the same eco-systems for decades, which makes the “ecological processes shockingly obvious” and affectively devastating²⁵. Rather than shocking and scaring audiences, the artist was inspired to work with the trauma and pain from a point that does not reproduce the pain and hurt, but by removing some of the shock effect and devastation of what glaciers actually sound like (very loud noise), by speeding up the geological processes to create an

other-worldly cryoscape. Moving forward she questioned field recording as the best strategy to tell the story of ice and moved forward towards exploring seismic data sonification as a strategy for sound sources.



Figure 4: The artist and programmer did field recordings and listened to the Ilulissat icefjord as part of their process. Source: Louise Foo (2021)

Presentation of the installation for stakeholders

Before moving into the prototyping phase, the installation was presented to the board of the Kangiata Illorsua – Ilulissat Icefjord Centre and implemented in drawings in the exhibition and architectural context. Through that process the artist presented questions about whether she was going to work with field recordings, questioning which data-sources to use, and based her presentation on concepts around a “data-driven sonic portrait of the inland ice.”

The artist explored the possibility of installing speakers in ways to communicate geolocation of stations and data sources; in one experiment speakers were mirroring their actual locations, in another experiment the speakers were placed based on the cardinal directions of events (East, West, North, South) and in the end, through conversation with the curators JAC Studio and Anna Domnick, who exhibited in the same space, *Eleven Movements of the Cryoscape* was placed on a 12-meter-long curved wall (figure 8) and a round bench was designed by JAC Studios in the center of the space, to facilitate a contemplative, prolonged listening experience.

Prototyping the Installation

In the fall of 2020, artist Louise Foo and programmer Yotam Mann were invited to do a three-week long residency at ITU's Affective Interactions and Relations Lab, in which a prototype of the installation was built before it was shipped to Greenland. They built a program to fetch streams of data from the GLISN database and PROMICE weather stations, to play from a project website⁴³ using the web audio API and browser-based audio mixing with Tone.JS. They set up controls for listening to seismic data (such as volume); which station, which time, date, speed, and durations (e.g., one week). Audio was routed using a Dante interface to respective channels over network) and an array of speakers were set up on stands in the Lab. The type of speaker landed on a speaker (A 'Diva Droplet by Gallo Acoustics), inspired by a photo of a seismic sensor in the ice sheet, inside a round shaped encasing. The round shape communicated 'a listening portal' into the ice, and removed the audience from the expectations towards the usual type of speaker box, which most often will reproduce recorded sound.

Experiments were made, to implement the monthly glacial data (reports of glaciers' calving and ice quakes) as well as data from weather stations in the melting areas around Greenland and connect those data to field recordings, but very quickly the soundscape felt predictable and "animated." The raw seismic data, on the other hand, turned out to provide an ever-changing otherworldly, *cryoscape*.

Four speakers were destroyed in the first few days because of too much low-end noise for the speakers to handle, and a low-cut filter was implemented. The following weeks were spent on extensive listening and reflections upon streams of raw seismic data together with people from the lab. The feedback was that people were drawn towards listening to the soundscapes for extensive periods at a time—it provided for a contemplative listening experience that moved them. A sense of "eavesdropping" the Inland Ice. Through that process the team was challenged by how one can compose a soundscape, based on a landscape, in decline? They were wondering if soundscape composition becomes didactic through the very act of composing and were, furthermore, wondering if data-sonification could help them avoid contributing to "The tradition of the appropriation of nature as a resource for the production of culture"²¹ and instead connect us more directly to those ecologies?

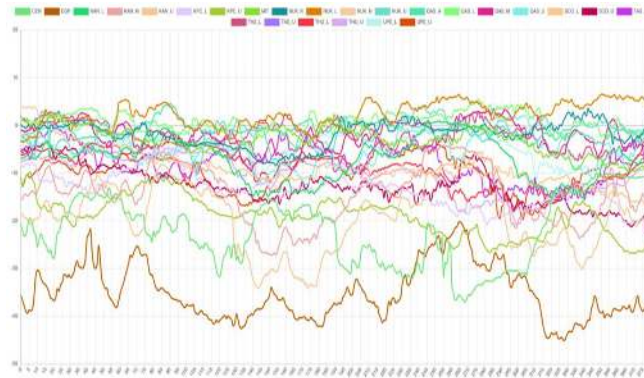


Figure 5 : Screenshot of weather data from PROMICE weather stations. Source: Yotam Mann (2020)

When listening to constant streams of data (before it has been flagged by a human) it is not possible to know what the data exactly entails. The team was questioning whether that was important? Is there such a thing as a hierarchy of the sounds we listen to? Are the significant glacial events (in the ears of science) for example, more important than the constant flux of other kinds of sounds? How do we choose what is important to listen to?

The raw seismic data sonifications were filtered slightly and a pinch of reverb was added to the channels (for aesthetic / mixing / sound quality purposes) and the overall sound landed on a low volume that draws your attention towards each individual speaker, and invites you to come close to each "listening portal." The number (eleven) speakers was decided based on the number of reliable sound sources (number of stations that will be transmitting at the same time). Through the process of prototyping the experience (in relation to a 12-meter-long curved wall) the speakers were placed in an array equally apart, in ear-height, with signs underneath each speaker with the station codes (notes of paper set on with tape) to signify which location each speaker was transmitting from. Furthermore, a map of Greenland was implemented, for audiences to connect the station names to their actual locations, as well as a digital calendar clock, to emphasize the duration / time of the installation; to support the near real-time listening experience.



Figure 6: Left: Map and calendar clock as implemented in the prototype, with speakers on stands and with station name signage. Right: Final map showing the eleven locations of the PROMISE weather stations. Source: Louise Foo (2020)

The program was built so that transmitting stations could change temporarily if a station is out of order for a period (which happens when, for example, one is out of order and something needs replacement). Since this is a permanent installation, we needed to account for several scenarios, the most extreme being one where no stations were no longer transmitting. We produced a solution where all data is always recorded, which fed into the idea of thinking about the installation as documentation – an archive for the future. After the prototype of the installation was finished, scientists Peter Voss and Andreas Peter Ahlstrøm and JAC Studios were invited to the Lab to experience the installation. Even though Peter Voss is familiar with seismic data and is looking at it every day from various scales, he pointed out how listening to the ongoing data in multiple streams at the same time gave him new perspectives on the Inland Ice and he stated that his guess was that 90% of what we hear in the raw seismic streams was ice-related. The last 10% is earthquakes, wind, waves, and human-made sounds which we found just as important to listen to, since the installation portrays the Inland ice as a living, breathing, evolving organism in the age of the Anthropocene, where human beings have made their mark on the soundscape.

Presenting the final Installation at the Icefjord Centre

As installed at the Icefjord Centre *Eleven Movements of the Cryoscape* can be experienced in different modes of listening (see Figure 7); as purely contemplative listening, supported by the bench in the center of the room, for people to sit and spend time with the overall soundscape created by the sum of all the transmissions. One can listen more exploratively by moving around in the installation and by getting close to each transmitting

speaker to listen in to specific locations. One can also connect the sounds with logic connecting sounds from locations to the map and the calendar clock.

The soundscape can also be listened to in conjunction with Anna Domick's photographs of slices of ice cores in the piece 'Inside the Ice Sheet' in which *Eleven Movements of the Cryoscape* becomes a soundtrack to her microscopic views inside the ice sheet, on a journey to past ice ages. Furthermore, a wall description outside the entrance of the room provides a contextual and conceptual frame for critical reflection.

On the Ilulissat Icefjord Centres website *Eleven Movements of the Cryoscape* is situated within the following exhibition context; "as a meeting between art and science in an installation, that through sound, images and a tactile universe both challenges and expands our perception and understanding of the ice sheets vast range and its significance for the world we are all part of" (Icefjord Centre Website, 2022). The Danish newspaper Politiken highlighted *Eleven Movements of the Cryoscape* in its review of the Ilulissat Icefjord Centre as "the final" that despite its underwhelming architectural priority "houses an installation of 11 speakers" The author explains how "Here you get a real-time auditory image of the enormous activity in the massif, which seems stagnant to the eye." He follows up with how he now "look differently at the icebergs" and how he senses "a deep-felt recognition of the connection between our way of life and climate change."



Figure 7: Installation view of *Eleven Movements of the Cryoscape*, that transmits near real-time seismic data as sound, from eleven locations in Greenland from the permanent installation at Kangiata Illorsua – Ilulissat Icefjord Centre. Source: Adam Mørk (2021)

Discussion and Conclusion

Throughout this article we have described the work and the thoughts going into the creation of *Eleven Movements of the Cryoscape*—a data sonification installation that can potentially lead to affectively engaging and sonically sensible spaces for listening, to activate ecological change. In *Eleven Movements of the Cryoscape*, the immediate goal is to allow the user to become affectively engaged by the soundscape to viscerally experience the earth moving and to, based on this, potentially rekindle his or her understanding of, and relationship to climate change. However, we have also explored how the sonification of the data can be used by seismologists to gain new knowledge about seismic events and we see potentials in a transversal aesthetics and believe it can be further explored. When we invited seismologist Peter Voss to listen to the ongoing streams of seismic data, he listened with curiosity and started connecting sonic phenomena with guesses of which glacial and tectonic events might be happening; that are not even 'flagged' as glacial events in the eyes of scientists, but still contribute with interesting sonic patterns. Future work would engage in a deeper evaluation of the audience's experience with the installation.

While we see a lot of potential in using data-sonification for a wide variety of artistic applications, as Kanngieser and Gibb Point out, aesthetic decisions must be made to translate data into the auditory domain. So, to follow up their question about how can we inform those aesthetic decisions and foster emotional impact beyond initial curiosity, that maintains complexity, while drawing out subtle nuances in data whose significance would be overlooked if communicated by any other medium we can point to seismic data conversion, as a quite "authentic" way to work with data-sonification, since there is more of a conversion going on than a mapping *per se*.

Eleven Movements of the Cryoscape is, among other things, inspired by the interdisciplinarity of ice studies in the humanities and social sciences offering alternative ways of framing and engaging the frozen environment⁴ posing questions like; is ice justice? This question has been challenged by researchers such as⁶ who asks if glaciers listen? While³⁸ analyzes the cultural framing of glaciers, Carey³ (sees an endangered species narrative applied to glaciers. Jackson (2015) exposes how glaciers are depicted as ruins, and Sörlin⁵⁸ refers to the present as a cryo-historical moment because "ice has become historical, i.e., that ice is an element of change and thus something that can be considered as part of

society and of societal concern.⁵⁸ This has led to further questions about what it means to portray or sonify ecologies. As an artist in a colonial perspective? As a woman in the male-dominated scientific realm of geology and glaciology? What can we learn about perception between human and non-human bodies? In response to those questions, although not all of them have been answered, it has thus been important to portray the Inland Ice, with respect to Indigenous peoples' relationship to the ice and a world-view; "where all aspects are interrelated, interdependent and indivisible. Furthermore, we refer to the installation as a documentation—pointing towards the media archaeological archives of the future³⁹ and have exchanged the term 'soundscape' with the term 'cryoscape', to emphasize the dynamic relationship between ice and people.³

In addition to conveying the effect of climate change on the ice sheet, *Eleven Movements of the Cryoscape* contributes to the exhibition by immersing audiences' bodies in the ice sheet from depths, corners and scales that would be otherwise impossible. It explores first-hand if we can foster a deeper connection, understanding and compassion (and planetary healing) by tuning in and "sitting with the world"—through listening? Through working on this project, we see immense potential in listening to more data that in similar ways can connect us to our planet and its context: listening outwards towards other planets and the sun, as well as inwards into sonic worlds of human and non-human interrelations. Furthermore, the project proposes to reach beyond art institutions as output and activate platforms for different (and potentially broader outreach) than traditional art institutions offer. In so doing, questions of how this type of artistic research contribute to technological, scientific, and environmental discourse are raised in a novel manner.

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References

- 1 Michael Bull, Marcel Cobussen, (Eds.), *The Bloomsbury Handbook of Sonic Methodologies*, NY: Bloomsbury Academic, 2021.
- 2 Rosi Braidotti, *Posthuman Knowledge*, Cambridge: Polity Press, 2019.
- 3 Mark Carey, M. Jackson, Alessandro Antonello, Jaclyn Rushing, "Glaciers, gender, and science", *Progress in Human Geography*. 40, 6m 2016, 770-793, DOI: <https://doi.org/10.1177%2F0309132515623368>
- 4 Mark Carey, "The history of ice: How glaciers became an endangered species", *Environmental History* 12, 2007, 497-527.
- 5 Linda Candy, Ernest. A. Edmonds, *Practice-Based Research in the Creative Arts: Foundations and Futures from the Front Line*, Leonardo, 51(1), 2018, 63-69.
- 6 Julie Cruikshank, *Do Glaciers Listen? Local Knowledge, Colonial Encounters, and Social Imagination*, Vancouver, UBC Press, 2005, p.6.
- 7 Anne Despond, Nicolas Reeves, Vincent Cusson, *Atmosphéries and the poetics of the in situ: the role and impact of sensors in data-to-sound transposition installations*, *Audio Mostly 2021*, Association for Computing Machinery, New York, NY, USA, 2021, 48-55, <https://doi.org/10.1145/3478384.3478422>
- 8 Dan Drollette Jr., *Bulletin of the Atomic Scientist: How fast is the Arctic ice retreating? Just listen to it melt*, June 2018, Retrieved April 30, 2022, <https://glacierhub.org/2020/04/16/acoustics-of-meltwater-drainage-in-greenland-glacial-soundscapes/>
- 9 Antonio B. Dobrowolski, *Historia naturalna lodu (The Natural History of Ice)*, Warszawa, Kasa Pomocy im., 1223.
- 10 Klaus Dodds, Sverker Sörlin (Ed.), *Ice humanities: Living, thinking, and working in a melting world*, Manchester University Press, 2022.
- 11 K. Doughty, M. Duffy, T. Harada, *Sounding Places: More-Than-Representational Geographies of Sound and Music*, UK: Edward Elgar Pub, 2019.
- 12 Jonas Fritsch, *Understanding Affective Engagement as a Resource in Interaction Design*, *Engaging Artefacts*, 2009, 1-9.
- 13 Jonas Fritsch, *Affective Interaction Design at the End of the World*, *DRS 2018: Catalyst*, 2018, 896-908.
- 14 Melissa Gregg, Gregory J. Seigworth, eds., *The Affect Theory Reader*, Duke University Press, 2010.
- 15 Isabelle Gapp, *Galvanizing glaciology: thoughts on an eco-critical art history* (January 2022), *Environmental History Now*, 2022, Isabelle Gapp: Retrieved, April 30th, 2022, <https://envhistnow.com/2022/01/20/galvanizing-glaciology-thoughts-on-an-ecocritical-art-history/>
- 16 Oskar Glowacki Department of Polar Research, Institute of Geophysics, Polish Academy of Sciences in Warsaw, Poland "Underwater acoustic signatures of glacier calving" O. Glowacki, G.B. Deane, M. Moskalik, Ph. Blondel, J. Tegowski, M. Blaszczyk *Geophysical Research Letters*, DOI: 10.1002/2014GL062859 retrieved from <https://www.youtube.com/watch?v=6jqTm3TMGvI>
- 17 GEUS - Geological Survey of Denmark and Greenland, Retrieved April 30, 2022, <https://www.geus.dk>
- 18 Félix Guattari, *The Three Ecologies*, Continuum Press, 1989.
- 19 GLISN Website, Retrieved April 30, 2022, <http://glisn.info>
- 20 Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene*, Duke University Press Books, 2016.
- 21 Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist Feminism in the Late Twentieth Century," in *Simians, Cyborgs and Women: The Reinvention of Nature*, New York; Routledge, 1991, 1985;1991, 149-181.
- 22 The Icefjord Centre, *About the House: The Exhibition*, Retrieved April 30, 2022, <https://isfjordscentret.gl/en/about-ilulissat-icefjord-centre/>
- 23 Karsten R.S. Ifversen, 2021, *Politiken, Arkitektur: 5 hjerter: Arkitektonisk lækkerbidsken opleves bedst på strømpesokker* (October 2021), Retrieved April 30, 2022, <https://politiken.dk/kultur/arkitektur/art8397563/Arkitektonisk-lækkerbidsken-opleves-bedst-pa-strømpesokker>
- 24 Michael Jackson, *Glaciers and climate change: Narratives of ruined futures*, *WIREs Climate Change*, 2015, DOI: 10.1002/wcc.1351.
- 25 AM Kanngieser, Rory Gibb, *Sonifying the world in Sounding Place*, Edited by Carolina Dougherty, Michelle Duffy and Theresa Harada, Cheltenham: Elgar, 2019, 153-160.
- 26 Gregory Kramer, Bruce Walker, Terri Bonebright, Perry Cook, John H. Flowers, *The Sonification Report: Status of the Field and Research Agenda*, Faculty Publications, Department of Psychology, 1999, 444.
- 27 Melanie Klein, *This changes everything*, Simon+Schuster Inc., 2014.
- 28 Bernie Krause, *The Great Animal Orchestra: Finding the Origins of Music in the Worlds Wild Places*. London: Profile Books, 2012.
- 29 Dennis Overbye, *Gravitational Waves Detected, confirming Einstein's theory*, *New York Times*, 2016, Retrieved April 30, 2022, <https://www.nytimes.com/2016/02/12/science/ligo-gravitational-waves-black-holes-einstein.html?searchResultPosition=1>

- 30 Jacob Kirkegaard, *Earside Out*, Museum of Contemporary Art, Denmark: Isfald, 2015, Retrieved April 30, 2022, <https://fonik.dk/works/isfald.html>
- 31 JAC Studios, *Projects: Ilulissat Isfjord Centre - The story of Ice*, 2021, Retrieved April 30, 2022, <http://jacstudios.dk/ilulissat-icefjord-centre-the-story-of-ice/>
- 32 Elizabet Leane Jeffrey McGee (Eds), *Anthropocene Antarctica, Perspectives from the Humanities, Law and Social Sciences*, Routledge, 2019.
- 33 Dorte Mandrup, *Work: Ilulissat Isfjord Centre*, 2021, Retrieved April 30, 2022, <https://www.dortemandrup.dk/work/ilulissat-icefjord-centre-greenland>
- 34 Brian Massumi, *Parables for the virtual: movement, affect, sensation*, Duke University Press, 2002.
- 35 Thomas J. Mitchell, Alex J. Jones, Michael B. O'Connor, Mark D. Wonnacott, David R. Glowacki, Joseph Hyde, *Towards molecular musical instruments: interactive sonifications of 17-alanine, graphene and carbon nanotubes*, *Proceedings of the 15th International Conference on Audio Mostly*, Association for Computing Machinery, New York, NY, USA, 2020, 214–221, <https://doi.org/10.1145/3411109.3411143>
- 36 Marcus Nüsser, Ravo Baghel, *The emergence of the cryoscape: Contested narratives of Himalayan glacier dynamics and climate change*, In: Benjamin Schuler (ed.) *Environmental and Climate Change in South and Southeast Asia*, Leiden: Koninklijke Brill, 2014, 138–156, https://doi.org/10.1163/9789004273221_007
- 37 Niels Bohr institute website: <https://nbi.ku.dk/english/>
- 38 Ben Orlove, Ellen Wiegandt, Brian H Luckman BH, *The place of glaciers in natural and cultural landscapes*, In: Orlove B, Wiegandt E, Luckman BH (eds) *Darkening Peaks: Glacial Retreat, Science, and Society*, Berkeley, CA: University of California Press, 2008, 3–19.
- 39 Jussi Parikka, *What is Media Archaeology?* Cambridge: Polity Press, 2012.
- 40 Bryan C. Pijanowski, Luis J. Villanueva-Rivera, Sarah L. Dumyahn, Almo Farina, Bernie L. Krause, Brian M. Napoletano, Stuart H. Gage, Nadia Pieretti, *Soundscape Ecology: The Science of Sound in the Landscape*, *BioScience*, Volume 61, Issue 3, March 2011, 203–216, <https://doi.org/10.1525/bio.2011.61.3.6>
- 41 Evgeny A. Podolskiy, *Toward the Acoustic Detection of Two-Phase Flow Patterns and Helmholtz Resonators in Englacial Drainage Systems*, *Geophysical Research Letters* 47, 2020, Retrieved <http://dx.doi.org/10.1029/2020GL086951>.
- 42 PROMICE Website, Retrieved April 30, 2022, <https://www.promice.org>
- 43 *Eleven Movements of the Cryoscape Project Website*, Retrieved April 30, 2022 from *Eleven Movements of the Cryoscape Project Website*, 2021, Retrieved April 30, 2022, <https://icefjord.nn.r.appspot.com/>
- 44 Zhigang Peng, Chastity Aiken, Debi Kilb, David R. Shelly, Bogdan Enescu, *Listening to the 2011 Magnitude 9.0 Tohoku-Oki, Japan, Earthquake*. In *Seismological Research Letters*, Vol. 83, Issue 2, 2012, 287–293, Seismological Society of America (SSA), <https://doi.org/10.1785/gssrl.83.2.287>
- 45 Andrea Polli, 2004, *Heat and the Heartbeat of the city*: <https://vimeo.com/127884090>
- 46 Andrea Polli, *Atmospherics/Weather Works: A Spatialized Meteorological Data Sonification Project*, *Leonardo* 38, 2005, 31–36, Retrieved from <http://dx.doi.org/10.1162/leon.2005.38.1.31>.
- 47 Andrea Polli, *Heat and the heartbeat of the city: Sonifying data describing climate change*, *Leonardo Music Journal*, 16, 2006, 44–45.
- 48 Andrea Polli, Joe Gilmore, *Sonification of measured (National Oceanic and Atmospheric Administration's Arctic program) and model weather data*, *Leonard Music Journal* 5:34, 2006.
- 49 Marty Quinn, *Research set to music: The climate symphony and other sonifications of ice core, radar, DNA, seismic, and solar wind data*, *Proceedings of the 7th International Conference on Auditory Display (ICAD01)*, Espoo, Finland, 2001.
- 50 Michael Quinton, Iain McGregor, David Benyon, *Sonification of an exoplanetary atmosphere*, *Proceedings of the 15th International Conference on Audio Mostly*, Association for Computing Machinery, New York, NY, USA, 2020, 191–198, <https://doi.org/10.1145/3411109.3411117>
- 51 Michael Quinton, Iain McGregor, David Benyon, *Sonification of Planetary Orbits in Asteroid Belts*, *Audio Mostly*, Association for Computing Machinery, New York, NY, USA, 2021, 72–80, <https://doi.org/10.1145/3478384.3478390>
- 52 Audrey Ramming, *GlacierHub: Acoustics of Meltwater Drainage in Greenland Glacial Soundscapes (April 2020)*, Retrieved April 30, 2022, <https://glacierhub.org/2020/04/16/acoustics-of-meltwater-drainage-in-greenland-glacial-soundscapes/>
- 53 Publication by Realdania, *Bog om Ilulissat Isfjords-center: En ganske særlig bygning på et ganske særligt sted*, 2021, Retrieved April 30, 2022, <https://realdania.dk/projekter/ilulissat-isfjordscenter>
- 54 Niklas Rönnerberg, *Sonification for Conveying Data and Emotion*, *Audio Mostly 2021*, Association for Computing Machinery, New York, NY, USA, p.56–63, <https://doi.org/10.1145/3478384.3478387>
- 55 Ben Rubin, *Hearld Thorp, Harbinger is a permanent public artwork by Ben Rubin and Jer Thorp commissioned for Brookfield Place in Downtown Calgary, Alberta*, <https://vimeo.com/250393598>
- 56 Margaret Schedel, David R. Worrall, *New Wor(l)ds for Old Sounds*, In *Organised Sound*, vol 19, 2014, 1–3, doi:10.1017/S135571813000356.
- 57 Isabelle Stengers, *In Catastrophic Times: Resisting the Coming Barbarism*, Open Humanities Press, 2009/2013.
- 58 Sverker Sörlin, *Cryo-History: Narratives of Ice and the Emerging Arctic Humanities*, *The New Arctic*, 2015, 327, Retrieved from http://dx.doi.org/10.1007/978-3-319-17602-4_24.
- 59 Anna Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*, NJ: Princeton University Press, 2015.
- 60 Sarah E. Truman, Stephanie Springgay, *The primacy of movement in research-creation: New materialist approaches to art research and pedagogy*, In M. Laverty, & T. Lewis (Eds.), *Art's Teachings, Teaching's Art: Philosophical, critical, and educational musings*, New York, NY: Springer, 2015, 151–164.
- 61 Salomé Voegelin, *Listening to Noise and Silence: Towards a Philosophy of Sound Arts*, NY: Bloomsbury, 2010.
- 62 Salomé Voegelin, *Sonic Possible Worlds: Hearing the Continuum of Sound*, NY: Bloomsbury, 2014.

63 Salomé Voegelin, *The Political Possibility of Sound: Fragments of Listening*, NY: Bloomsbury, 2018.

64 Chris Watson, 2003,
<https://chriswatsonreleases.bandcamp.com/track/vatnaj-kull>

65 David Worrall, *Sonification Design: From Data to Intelligible Soundfields*, CHE: Springer, 2019.

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