Glacial Sensing: Entanglements of Sound and Vision

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ABSTRACT

What is the relationship between vision and sound in more-than-human environmental sensing? This article traces an ethnography of glaciologists' experiences with technological sensing systems that surpass human sensing capabilities, producing an expansion of sensory knowledge that enmeshes both imagery and acoustics. Sound and vision emerge no longer as separate modalities, but in a united vocabulary of sensing in which the human and the machine are collaborators, producing a multi-eared and multi-eyed system by which icebergs and glaciers are observed and perceived as a quickly morphing process, rather than as a static object. It examines the manifold aesthetic variations and conversions of data from acoustic sensing systems into sounds and images that work together to reshape the scientific imagination of the cryosphere. This process ultimately reveals how technology changes perceptions and how glaciers, human bodies, and machines become intertwined with each other in a more-than-human system that holds the promise to diversify knowledge.

KEYWORDS

climate, environmental studies, digital media, media studies, technology and science, geography, glaciology

Visual Anthropology Review, Vol. 0, Issue 0, pp. 3–23, ISSN 1058-7187, online 1548-7458. © 2023 The Authors. *Visual Anthropology Review* published by Wiley Periodicals LLC on behalf of American Anthropological Association. DOI: 10.1111/var.12312

A More-Than-Human Umwelt

The last few decades have produced intriguing ethnographies about the overlap between human and nonhuman worlds: Do glaciers listen to humans (Cruikshank 2007)? Are dogs' dreams translatable to humans (Kohn 2013)? How do robots see Mars (Vertesi 2015)? Can scientists hear bacteria screaming (Roosth 2009)? These works have opened broad new horizons for understanding sensory experiences and their relationship to knowledge. These questions are not new but quite perennial: What is a field of flowers to the vision of a bee that sees only starry shapes, asks Jakob von Uexküll in *A Foray into the World of Animals and Humans* ([1933] 2013)? What is the underwater landscape for a seahorse that theoretically sees 16 more shades of blue—shades of blue that humans cannot biologically see? How do scientists navigate and experience underwater soundscapes, a spatial system that humans do not naturally inhabit for extended periods of time (Helmreich 2007)? Does the environment—the *umwelt*—change meaning depending on the organism that senses it? If humans could "see" and "hear" like other organisms, how would that change our perception, experience, and meaning of a meadow, a seabed, a river, or a glacier? Would we learn more about the environment? In other words, is sensory expansion also the expansion of *knowledge*?

Uexküll's concept of the *umwelt* is a very situated and embodied environment. Distinctly non-Cartesian, the *umwelt* is the biological sensorium entangled with the environment itself. When ready to harvest, a meadow of lavender might be experienced by the human as a combination of a bluish-purple field along with a distinct herbaceous and floral scent. To the bee, the meadow is ready for harvest when it changes from a series of straight black-and-white lines into an expanse of cross-like star shapes (seen as pollen in the bee's visual system). Both environments—the human's and the bee's—inhabit the same location and the same space in entirely different sensory modalities that communicate differing significations to each species. What, thus, can we learn from other species?

In this article, I chart the methods by which glaciologists render glaciers "listenable," how they are heard through more-than-human acoustic sensing systems and then visualized as an elastic body with its own morphology. While there are many robust ethnographies of how scientists form and employ sensory vocabularies to understand nonhuman bodies like bacteria (Roosth 2017), exoplanets (Messeri 2016), and ocean waves (Helmreich 2015), they often address sound and image as separate scientific objects. I am concerned with how vision and sound are entangled in scientific observations and

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imaginations of ice sheets and glacial processes. A multisensory approach to sound and vision is imperative for immersion into the fluid, dynamic, and quickly morphing nature of glaciers and icesheets. Glaciers, like hydrological systems, are an unresolved natural process that is hard to quantify (Hastrup 2013; Hastrup and Hastrup 2015) when it is an ongoing choreography of transformations from one state to another (for example, in the elusive nature of ice as neither rock, nor soil, nor water). Dealing with such unstable and hybrid entities requires both scientists as well as the general public to question the idea of nature and to reconsider the vast range of scales (Hastrup 2013, 14) in which it can be defined or expressed. As historian Lorraine Daston (2016, 47) argues in her essay on the science of clouds, it is very difficult to develop a stable system of representation of natural processes that entail infinite variability—that is, where everything is turning into everything else all at once. There are therefore difficulties with material limitations of time, space, and perception that impact what can be observed and how. While these constraints are not fully resolved with more-than-human sensing systems, the process certainly expands the limits of what can be sensorially experienced.

By consequence, I will aim for a thinning of the border between visual anthropology and the anthropology of the senses. On the one hand, an extensive discourse of multisensory experience exists in visual ethnography that addresses how filming and editing methods in ethnographic film and photography represent and invoke broader sensory experiences—for example, expressing "noise" or a haptic sense of "having been there" (Grimshaw 2001, 93–96; MacDougall 1997, 222; Pink 2006, 42). On the other hand, there have been calls for an anthropology of sound and acoustic space (Cox 2018, 6; Feld and Brenneis 2004; Helmreich 2007, 622) that is developed enough to be on par with visual anthropology. Amid this, there has also been an ongoing discourse calling for a more multisensory anthropology—arguing that sight and sound are already dominant senses within Euro-American culture. An example is in the legal and justice system where only valuations of sight and hearing are considered evidential, with touch and smell relegated to a more symbolic or even metaphorical status (Howes and Classen 2013, 96–100). I would like to offer some continuity to this discourse, while still arguing that sound persists as quite secondary to that which is strictly "visual" in evidence-making cultures. Furthermore, within the discourse on sight, sound, and touch, I would like to focus on their sensorial fluidity—that is, the role of

FIG. 1

acoustic "imagery" and "tactile" sound in actively constructing visual knowledge itself. In doing so I am concerned with how vision in more-than-human remote sensing is already multisensorial beyond a metaphorical or symbolic role and is also beyond and other than synesthesia.

Observing images of famous glaciers (Aletsch, Moreno, and Baltoro, among many others) limits them to their visually observable material properties (Figures 1 and 2). The result is that a famous glacier can become reduced to an iconic symbol that simplify it as *object* rather than *process* to the passive viewer, further widening the gap between scientific understanding and cultural imagination of its life cycle (depending, of course, on the content of the articles that accompany the images). Camera-based images of the world's famous glaciers, while identifiable by the iconic topographies that surround them, are not identified the same way by glaciologists, who see them as dynamic forces—that is, vector fields with associated sets of patterned events. Glaciologists describe glaciers as incredibly hard to make images of and visualize, describing them as elastic and resonant bodies, perpetually moving and "shimmying" every day while appearing static to the human observer in a moment of time. Neither rock, nor soil, nor water, a glacier is an intermediate entity between different kinds of matter. The problem, however, is that the world beneath the topmost surface of the glacier is extremely hard to capture or illustrate with imaging technologies. Some of its aspects can even be nearly "un-imageable," if not unimaginable. On

FIG. 1 A photograph of the Aletsch glacier in Valais, Switzerland, taken in June 2011. *Source*: Robert J. Heath.

FIG. 2

a more abstract level, this problem is well known to visual ethnographers. There has been a vibrant discourse about how the most manifestly visual facets of the world might inhibit its understanding, given that visuals (particularly in film and photography) usually account for aspects of reality that are explicitly "observable" or "recordable" (MacDougall 1997, 217; Pink 2013, 8–11). To overcome this problem, the ethnographer may have to account for imagination, conversations, and other cognitive processes that are intangible and not immediately categorized as strictly "visual" (Howes 2009; Pink 2013, 23).

Similarly, despite the proliferation of visual technologies, glaciologists need acoustics and other sensory modalities to understand a glacier as a multidimensional and unresolved natural *process*, rather than an *object*. For this, remote sensing practices are increasingly augmented with more-than-human capacities to record wavelengths outside human sight and hearing to draw unexpected and sometimes even unrecognizable portraits of well-known glacial topographies. As I will demonstrate through the imagery in this article, the glaciologist may sometimes even need to unlearn what a glacier typically looks like to their eyes to properly study it as a process. In so doing, I offer an ethnography of more-than-human sense perception and knowledge. My method is para-ethnographic, where the glaciologists I have carried out fieldwork with are

FIG. 2 An aerial photograph of the Baltoro glacier in Pakistan, taken in October 2005. *Source*: Guilhem Vallut.

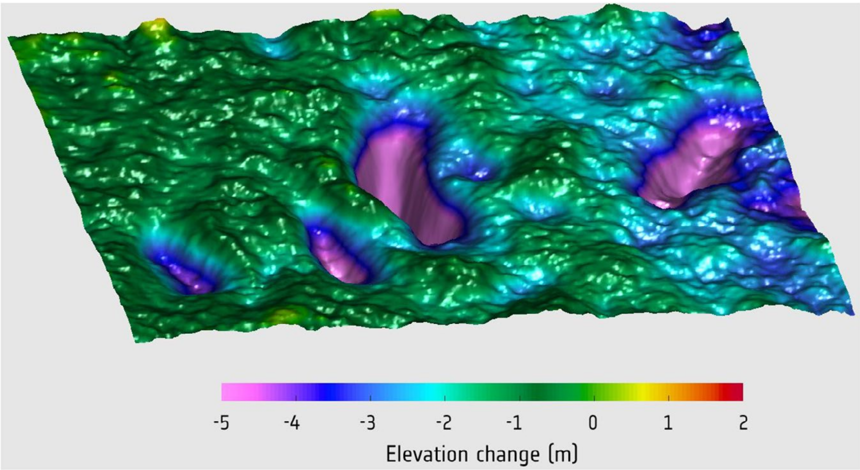

FIG. 3

better described as collaborators than as informants, and where my role has been actively involved in glaciologists' own fieldwork on glaciers, the sonification and imaging process, as well as through some training in how to use the technologies I describe. This article draws from data that includes seismic signals, hyperspectral imagery, acoustic sensing practices, and other kinds of sensory data that informs our cultural and media understanding of what is happening to glacial environments amid climate change, particularly regarding emerging 4D models and digital twin projects of Antarctica (Figure 3) currently in progress. It is based on three research components of a larger project on glacier seismology: (1) my ethnographic observations carried out with glaciologists at the University of Chicago that focus on calving records of the B-15 iceberg—the world's largest recorded iceberg to have calved off Antarctica; (2) my fieldwork with Swiss glaciologists from ETH Zürich to install seismic sensors on the Rhône Glacier in Switzerland; and (3) materials and methodology from an in-progress audiovisual art installation in artist residencies employing the combined data from the abovementioned records.

FIG. 3 A model of the subglacial lakes underneath the Thwaites glacier in Antarctica. Models like this are used for creating Digital Twin and 4D simulations of Antarctica, virtual replicas that are so complete and accurate that they can be used for decision-making. *Source*: Noel Gourmelen, University of Edinburgh, 4D Antarctica.org.

The Case of the B-15: How to Listen to an Iceberg Calving

In *Do Glaciers Listen?* anthropologist Julie Cruikshank (2007) recounts oral history and storytelling traditions among First Nations communities in the Arctic Yukon region. Among the belief that glaciers can listen to and take offense from jokes made by humans living around it, she recounts First Nations storytelling traditions passed from generation to generation.

FIG. 4

These traditions are ones in which humans recognize that glaciers are aware of their activities, smells, and sounds—the glacier itself figuring as an animate and resonant body capable of sensing (Cruikshank 2007, 47). While my fieldwork is not a storytelling tradition nor one that precedes the emergence of Western scientific rationality, I ask questions from another position on this spectrum: In what sensory register can humans hear a glacier speak? How do they understand its language and extract meaning from it? To illustrate these questions, I turn to the case of the B-15 iceberg in Antarctica, sensed acoustically by glaciologists at the University of Chicago and the University of Colorado Boulder with whom I began to listen to glaciers and ice sheets as part of my ethnographic research in 2018.

In the year 2000, a group of seismologists observed a pattern of earthquake signals reaching Hawaii from the Antarctic (Talandier et al. 2006). Some years later, this group of glaciologists discovered that the signals were coming from the Ross Ice Shelf in Antarctica, an early prediction that an iceberg was about to break off, though they did not quite recognize the signals as a premonition at the time. Sure enough, headlines flashed across world media later that year, when the largest recorded iceberg in history called the B-15 broke and wandered off into the sea (Figure 4), a proof that the ice in the poles was

FIG. 4 A MODIS spectral image of the B15 iceberg in 2000 as it drifted off into the sea. This image is computed from 36 spectral bands from the satellites called *Terra* and *Aqua*. The mirrors mounted on the satellites act like a skin off which the reflected waves bounce, producing values that correspond to heat, moisture, and humidity. Its extremely sensitive infrared sensors capture wavelengths of light that humans cannot see. *Source*: NASA Visible Earth.

melting faster than previously imagined. A group of scientists in the American Midwest had been seismically observing the ice shelf for over a year, studying the fragile structure of the ice through them. A new kind of science emerged as scientists realized it was possible to hear the *singing of the ice* as it cracked, sheared, slid, and trembled beneath the surface. They formed a scientific vocabulary from musical and choreographic terms to describe these sounds as they sought to demonstrate the physics of the ice sheet—the *shimmying*, *trembling*, *buzzing*, and *gliding* of the different layers. There are many meanings of these sounds to the ears of glaciologists, which convey subsurface movements of the firn[1]—an inner layer of an ice sheet or glacier that sits between surface snow and the hard ice underneath. The sounds are captured through seismic sensors that record the physics of the deep layers of the ice sheet. Each frequency in the data represents a process—the formation of a crack, a "spectral glide" (ice sheets grinding against each other), or the melting of the surface snow. However, these scientific imaginations and conjectures rely on image and sound in symbiotic ways. Acoustic signals convey the speed, texture, and the nature of materials through vibration. Month after month of immersion into this data, glaciologists see, dream, and hear this "rumbling of the icebergs … as it is screeching" (McGavin 2013, 61). The imagination of movement is also an audiovisual exercise. For example, scientists describe the trembling of the firn layer as "shimmying," (MacAyeal 2018) invoking the shakes and sways of a dance movement originating in North American jazz. Sound and image are corroborated with each other to bring these fragmented vignettes together into a comprehensive model of the B-15 calving event and why it happened. As one of the glaciologists from the team told me:

> *The signals convey the viscosity of the melting ice as if it's thick and slow in movement like honey trickling; it is very textured. … The signals are infrasound; they are below the range of human hearing—but when we compute them into sound in an audible frequency, they do not give a sound we could have heard anyway on the ice sheet. They're 4D, you could say, you are hearing the physics of ice movement over a two-year period in exactly 2.5 minutes of sound. The B-15 did not calve overnight, it was a process that probably started much earlier and unfolded slowly.*

He then showed me a spectrogram of the calving event—a series of color-coded wavelengths of sound that express the different frequencies.

> *Ultimately, visual analysis of these signals serves us much better. But in the first step, the sound helps us to get an impression and quickly isolate events of importance over this two-year period we are looking at. Because who wants to search for the event in endless rows and tables of numerical data?*

The visual sense has often been referred to by historians and geographers as the master sense of modernity and rationality for good reason (Cosgrove 1998, 3–5; Daston 2015, 15)—yet alongside this history there is also a parallel history of acoustic space and its close relationship to vision. From Alexander Laszlo's idea for an 18th-century color organ (Figure 5) to Henri Labrouste's *viseur acoustique*, or acoustic sight (Figure 6), and World War I experiments in "acoustic images," questions of what is scientifically and technologically visual are occasionally intertwined with acoustic space (Ouzounian 2021, 39–43). In anthropology, it is telling that visual anthropology exists now as a solid subfield with an expansive body of ethnographic methods, whereas the other senses are largely consolidated into the category of sensory ethnography. There are many compelling ethnographic works on sound, language, and human–environment relations, like Alfred Gell's (1995) ethnography of the arboreal language of the rainforest in Papua New Guinea and Edmund Snow Carpenter's ethnography of First Nations communities in Arctic Canada, where he argues that the "Eskimo lives in the realm of acoustic space" (Carpenter et al. 1973, 33), a more richly textured landscape than the homogeneous and unbounded visual landscape of snow and ice (Ouzounian 2007, 47). Still, these ethnographies echo perspectives that relate sound to the structure of so-called "pre-literate" societies and vision to the Western imagination (Ouzounian 2007, 54), fracturing the modalities of sound and vision beneath the argument that some societies happen to be more visually oriented than others (Pink 2006, 44). At the same time, there have been calls for an anthropology of sound and acoustic space (Feld and Brenneis 2004; Helmreich 2007, 622) and expansive literature on the use of acoustic space as a tool of military and nationalistic power (Goodman 2010). Yet we may want to look further to understand the symbiosis of acoustic space and vision as entangled and intertwined in the scientific imagination. Even satellite imagery, which often appears photographic when rendered, is constituted by the tactile and acoustic choreography of light waves that bounce off the mirrorlike surfaces of satellites. These values may be read as temperature, heat, or color all at the same time; they are multiple sensory modalities at once. In this sense, vision can sometimes supersede the classic question of optics and extend to other realms of the biological sensorium—that

FIG. 5

FIG. 5 A caricature of Louis-Bertrand Castel's "ocular organ" by Charles Germain de Saint Aubin, circa 1780. *Source*: Waddesdon, The Rothschild Collection (The National Trust).

is, images can conjure tactility and sounds can produce visual affordances.

To return to the case of the B-15, it is also less discussed in studies of remote sensing that satellites, sensors, and scanners provide signals and information in the form of *liminal*, indeterminate[2] data that is not already an image nor a sound but at best "imagelike" and "sound like" until it is processed (Mirza 2020). Radar and seismic signals convey echo, reverberation, vibration, and resonance in frequencies

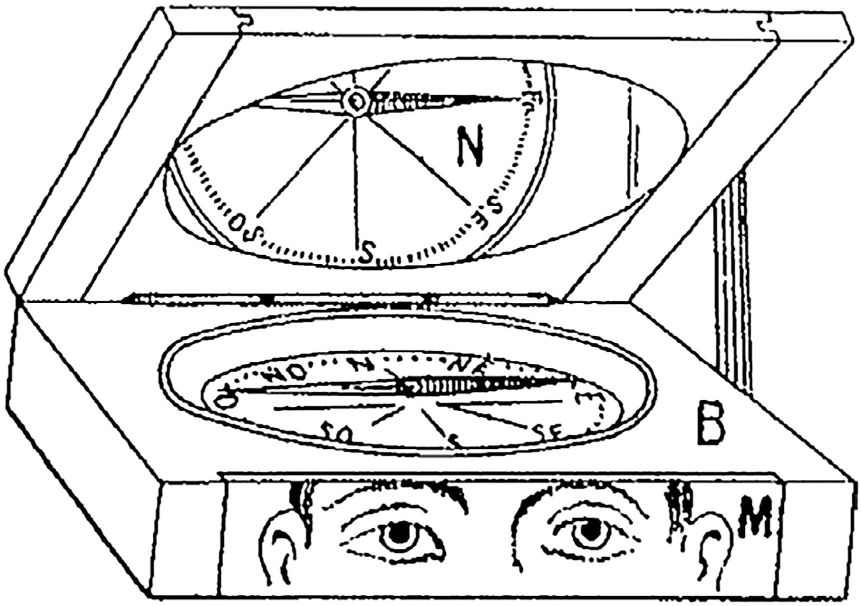

FIG. 6

that humans cannot detect directly but might well be detectable by dolphins, bats, goldfish, and other animals that sense along the spectrum in which these signals lie. These signals are a choreography that transmits the materiality of the ice, bedrock, and its various movements as acoustic waves that bounce, reflect, and ricochet off the different materials and their densities in these environments. As a result, even the most delicate *humming* and *buzzing* of the deep ice then becomes detectable. To humans, these signals are oddly liminal—they are neither immediately sound nor image but can be realized as pictures and sounds depending on the choices and decisions of the analyst. Thus, a distinctive feature of more-than-human sensing is this liminality: sensors capture signals that require "transduction"—that is, conversions of signals between and across different media and sensory modalities (Helmreich 2007, 622)—before they can render a meaningful natural object such as a glacier, a mountain, or an ocean current.

Drawing from physics, Gilbert Simondon's work expresses transduction as a process by which energy is converted from one state to another: as Paulo de Assis (2017, 695) describes it, "a dynamic operation by which energy is actualized, moving from one state to the next, in a process that individuates new materialities." In music and the arts, as much as in science, transduction refers to the beginning moment in which an "infinite reservoir of possibilities exists

FIG. 6 Henri Labrouste's viseur acoustique. *Source*: MIT Press Reader.

… a cloud of high energetic potentialities" (696). Here the virtual or "spectral" signals are not ghostly doppelgängers of some real thing in the world but echoes of an actual material perceived in the moment. They are not representations of an *actual*, lying somewhere in-between that traditional categories of "subject" and "object." They are their own kind of materiality. As I play the sound on my laptop, the speakers vibrate, and the pitches and tones become less clear as the body of the computer speakers begins to quiver. *Is what I am hearing coming from the track, or are my laptop speakers making the sound because of the intensity of the vibration?* I ask. My collaborator answers: *It's vibration, and hence this [tactile] quivering is just like the seismic sensor's membrane must have buzzed underneath all those layers of glacial ice, just in a different set of frequencies.*

The signals are at once tactile, imagelike, and acoustic. The possibilities of rendering them as different kinds of images and sounds are manifold. Because these signals can be realized in various formats, they have the potential to create meaning differently in each conversion—or each *transduction*. Anthropologist Stefan Helmreich (2007) borrows this terminology into "transductive ethnography" in which he recounts his underwater experiences of sound and acoustics on a "submarine cyborg." He argues for understanding sensory immersion in terms of the cultures of hearing and listening, transduction being a process where variations in one medium are converted into corresponding variations in another medium (622). In my ethnographic work with glaciologists, these transductions occur between sound, image, and imagination, where sound and image collaborate in a "simultaneous restructuring of matter and meaning" (622). The sensory relays between image and sound allow for new meanings to be generated, and with its new imaginations and the rephrasing of facts, such as how fast (or slowly) a glacier might eventually melt despite periods of greater activity.

The glaciologists have been taking the data and converting the signals to audible sound to isolate events and activities of significance in the B-15 ice sheet that have led up to its calving. They watch out for tones that represent "spectral glides"—a grinding of two opposing ends that signals the beginning of a crack in the icesheet. They pay attention to the "humming" at the base of glaciers (Heeszel, Walter, and Kilb 2014), where tiny tremors take place at the point of contact between ice and bedrock. They look for "whistling" that expresses the effect and pressure of wind upon the ice (Chaput et al. 2018). The cryosphere, in this way, speaks through its physics as a song. Glacial seismologists visualize the vibrations as colored frequencies to understand the glacial ice as it slides over its bedrock. The glaciologists that produced the sonification of the B-15 iceberg were looking at a score, one that can even be expressed in musical notation (Figure 7, Audio 1). However, a broad range of visual and sonic media correspond with each other as part of the entire process—an image of the glacial topography created with radar (Figure 8), a spectrogram of color and waveform (Figure 9), and particle motions animated through my own creative work with the data as part of an art-science collaboration that parallels my ethnographic research (Figures 10–12).

An Acoustic Sensing System on the Rhône Glacier

In July 2020, I participated in fieldwork with a team of glaciologists from ETH Zürich to install an acoustic sensing system on the Rhône Glacier. A foggy swirl of rain and hail obscured our vision of the surroundings of the glacier as a storm built over the skies. To install the system, we had been drilling small holes down to the glacial bedrock over the past week, not knowing what lay below the gray and brittle layer of glacial ice upon which we stood (Figure 13). After drilling down to the bedrock, we placed seismic and water pressure sensors at the point of contact between the ice and the underlying rock. While trekking over the ice on our way to the site, the glaciologists observed variations in how brittle or how stiff the ice was. *Sometimes you just have to step on it to know; walking is itself an observation*, one of them remarked. However, even though we were walking onsite, our human observations were not enough. *There are tiny little quakes happening everywhere underneath our feet, just 170 meters below where our feet touch the glacial surface, and yet we cannot feel them. For that, we need to install the acoustic system*, explained the glaciologist.

The sensors used to capture that data are like thin tympanic membranes that vibrate like the skin of a drum when something moves or when water currents exert pressure on it. They mimic the way a human eardrum responds to changes in air pressure and speed. *Every time the sensor detects an event in the glacier, think of it as the way your ear pops due to air pressure changes when you are landing from a flight*, explains a team member.

> *It's a thin membrane, and it picks up on the different kinds of pressure changes and movements, making its thin surface buzz and vibrate like a drum. It's not only picking up movement but also pressure changes in the ice that can help us observe how the glacier moves and melts.*

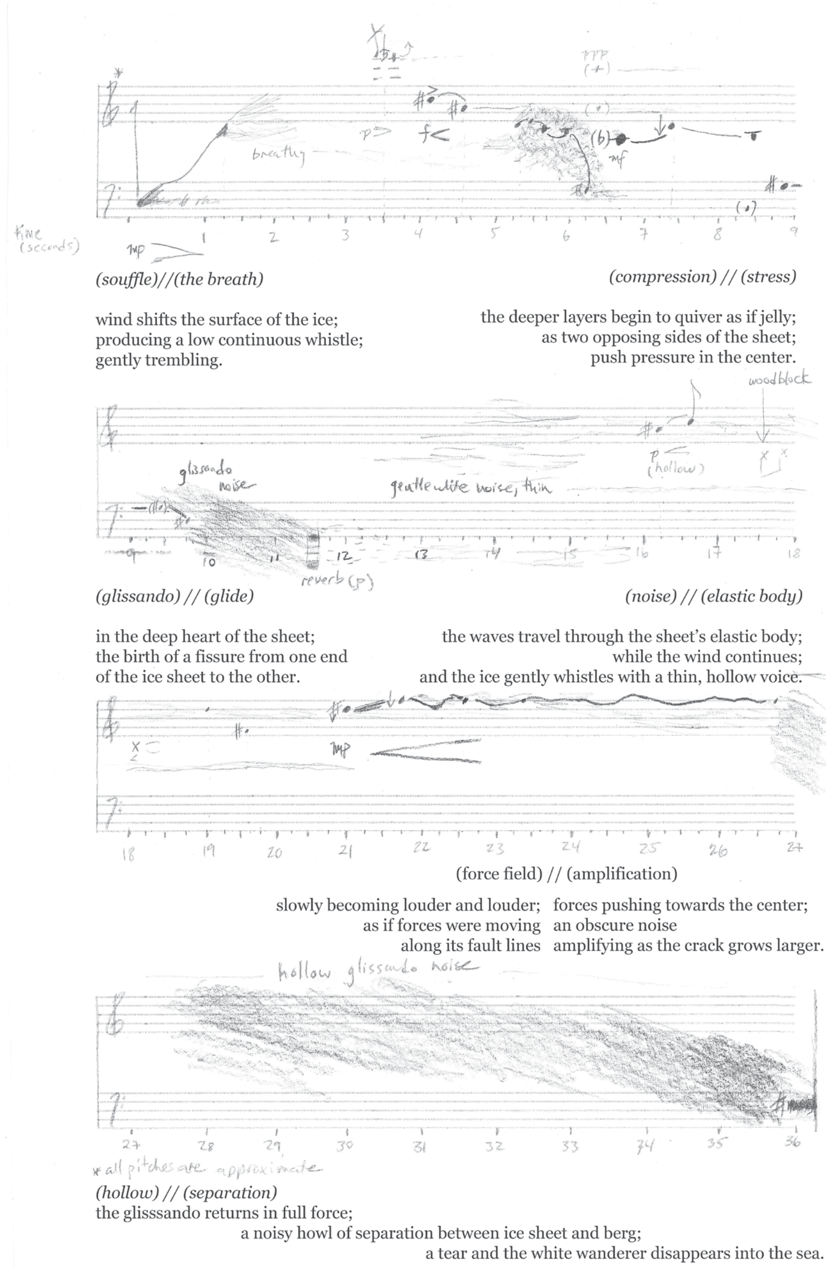

FIG. 7

So far, climate models built by scientists across the world have been trying to assess the speed of deglaciation in the contemporary era, and thus in times to come. This ETH Zürich team is interested in how the bedrock and glacier interact and how strong

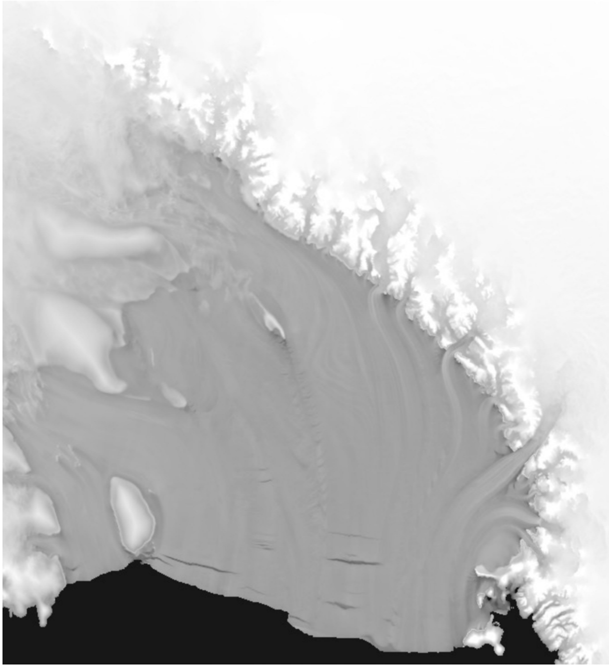

FIG. 8

the friction between the two is. This is also relevant in a broader sense to the initiatives of the Swiss government to build maps of hidden topographies such as the lakes and valleys that will emerge after full deglaciation in the Swiss Alps.

By itself, this acoustic system is a rather expensive and rare kind of experiment. We were installing a total of 25 sensors at the bedrock of the glacier to transmit signals from the point of contact between ice and bedrock where an ongoing choreography of tiny quakes is happening. One of the team members has come up with a novel idea to install a tiny camera instead of the seismic sensor at the 170-meter contact point with the bedrock in the hope that a camera might be able to image what's happening down there. Six months later, he retrieves the footage and is utterly disappointed. *This was useless; the footage shows some debris and helps make a time-lapse movie that expresses the speed of some movements. But it tells us nothing we did not know before. I am going back to the acoustic system.*

Sensing is a multimodal process. Sounds convey images, textures, and hapticity. They also evoke materials, directions, and movements that can be expressed visually. In studying something as complex as a glacial movement, it seems obvious that we should be considering sound and image together, but it is a matter of expertise. In technocratic Antarctica, anthropologist Jessica O'Reilly (2016, 30) studies glaciologists' methods

FIG. 7 The B15 Iceberg Score. This score was created by the author in collaboration with composer and artist Jessica Feldman during an artist residency while developing the data from the B15 ethnography into a sound and video installation. The installation is a feature that runs parallel to this ethnographic research. *Source*: Jessica Feldman (composer) and Saadia Mirza (text/transcript).

AUDIO 1. This audio excerpt has been created from the seismic records of the B-15 iceberg, computed and rendered by Rick Aster (University of Colorado Boulder) and Douglas MacAyeal (University of Chicago). The audio represents several months of data compressed into a few minutes of sound.

FIG. 8 A radar-sensed model of the Ross iceshelf from which the B15 iceberg calved. This image has been produced as a 3D model using the acoustic nature of radio waves to map the ice shelf. *Source*: REMA.

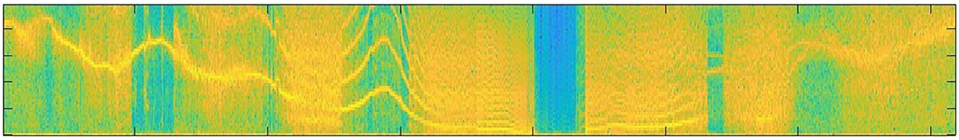

FIG. 9

of sensory observation through their movements, touch, and physical observation of ice samples in Antarctica, arguing that sensing must be treated as anything but “instinctual and primitive” but instead bound up with boundaries between disciplines and expertise. Seeing and hearing are thus not a given; they are techniques and practices. *We can all hear and see, but how are your ways of seeing and hearing different from mine?* This is perhaps even more true in more-than-human sensing systems such as the one installed on the Rhône Glacier or the one used to sense the B-15 calving event, where the expert grapples every day with how the acoustic sensors perceive the deep glacial environment differently from how humans hear and image it. Thus, the sonic and visual conversions and transductions must be understood in binaural and stereographic terms—humans have two ears and two eyes to make sound and sight intelligible in space and to understand its source and transmission. It is a richly textured spatial system. Sensors, while rich in their range of light and sound wave information, record and transmit signals without the need for spatial texture. For the expert to immerse themselves in the data, some level of processing, translation, and conversion (i.e., transduction) is needed to align human and machine sensing.

A Multi-Eared and Multi-Eyed System

When a glacier or body of water is sensed seismically as a watershed rather than a terrain model of its undulating rock and soil, it is a particularly fluid and porous entity. It needs a tentacular intelligence to be apprehended. This means it becomes messy in terms of the many sensory values that give it anthropocentric meaning, while itself being sovereign in terms of its own fluid processes, which are still largely mysterious to scientists and researchers. This includes phenomenological observations of when a recording “sounds like” a tremor or an infrared pixel formation “looks like” a water reflection versus when certain infrared band values are computed as a heat map or seismic signals are numerically interpreted as harmonic and elastic waves with algorithms. In this process, more-than-human sensing systems are a collaborative *ensemble*—to borrow from philosopher Gilbert Simondon (1980)—in which machines and humans are hierarchically equal and work

FIG. 9 A spectrogram of the calving event of the B15 iceberg. The colors represent frequencies captured across time (represented horizontally). Events were recognized by the glaciologists in the patterns and shapes of the frequencies. *Source*: [Coded in Matlab by Douglas MacAyeal].

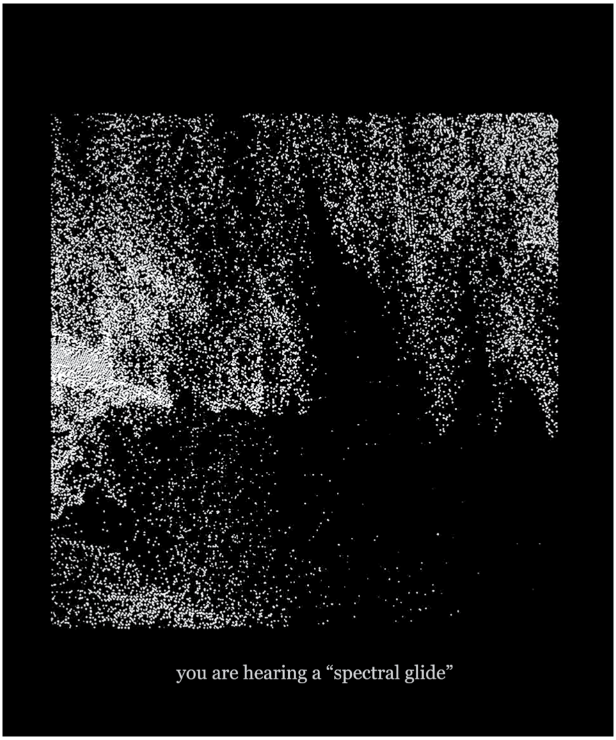

FIG. 10

together to create new registers of knowledge through transductions and variations of sense, sound, and vision.

To reference a question that I asked at the beginning of this article: If we could sense the meadow as bees do, would we see a patchwork of starry pollen? Would that sensory expansion also be an expansion of cultural and scientific knowledge? To be more-than-human is to inhabit a multitude of diverse sensory modalities. As argued before, the liminality of these signals transmitted remotely through sensors and scanners produces an indeterminate dataset—that is, the question of where a glacier begins or ends, when a calving process starts, and the anticipation of where the next fracture will appear depends entirely on which spectral bandwidths and frequencies are selected, classified, and computed by human experts and analysts. Transductive processes and conversions into corresponding media can express the glacier or ice sheet as a hazard (to nearby settlements) or as a resource; as a topography or a territory; a fixed border or a fluid watershed; a mountainous bedrock or a temporal flow of ice. While this may fuel governments to find ways of asserting politics regarding "what" lies "where" for nationalist interests, my research with glaciologists shows that it also finds creative and expressive ways of complicating that "what" and "where" in ways that can speak to

FIG. 10 Screenshots from an animation sequence that uses a particle system to visualize the acoustics and movement of the B15 calving event. This one shows a spectral glide, which is often described as the vowel quality of a tone. To the glaciologists, it expresses shear force in the ice sheet. *Source*: Mirza. These images were created by the author during an artist residency while developing the data from the B15 ethnography into a sound and video installation. The installation is a feature that runs parallel to this ethnographic research.

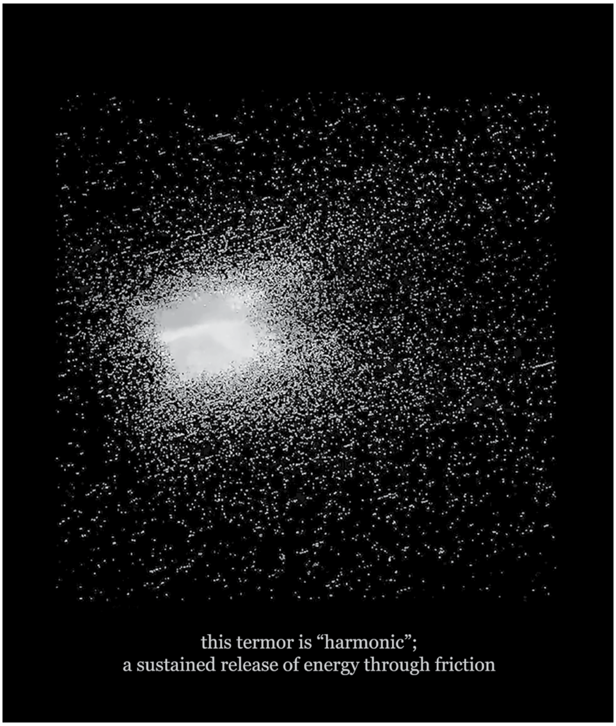

FIG. 11

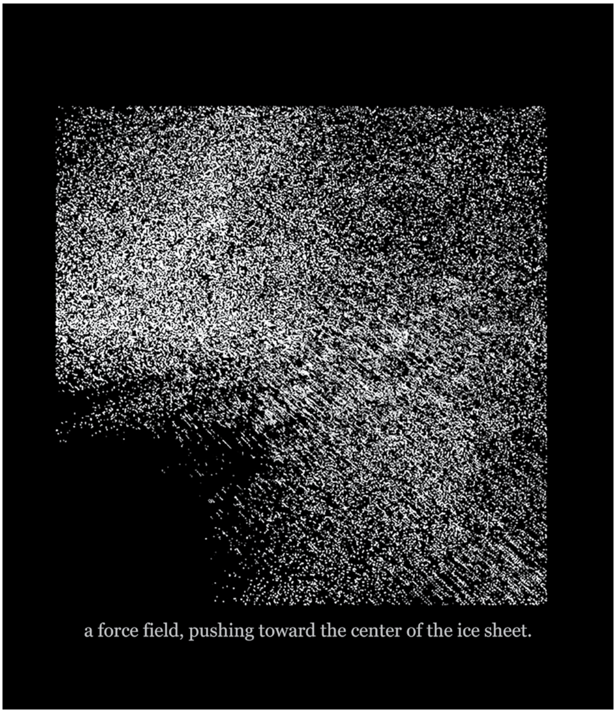

FIG. 12

FIG. 11 Screenshots from an animation sequence that uses a particle system to visualize the acoustics and movement of the B15 calving event. This one expresses a harmonic tremor, which is often associated with underground movements. *Source*: Mirza. These images were created by the author during an artist residency while developing the data from the B15 ethnography into a sound and video installation. The installation is a feature that runs parallel to this ethnographic research.

FIG. 12 Screenshots from an animation sequence that uses a particle system to visualize the acoustics and movement of the B15 calving event. This one expresses the shear force from two opposing sides of the sheet, causing a fracture in the center. *Source*: Mirza. These images were created by the author during an artist residency while developing the data from the B15 ethnography into a sound and video installation. The installation is a feature that runs parallel to this ethnographic research.

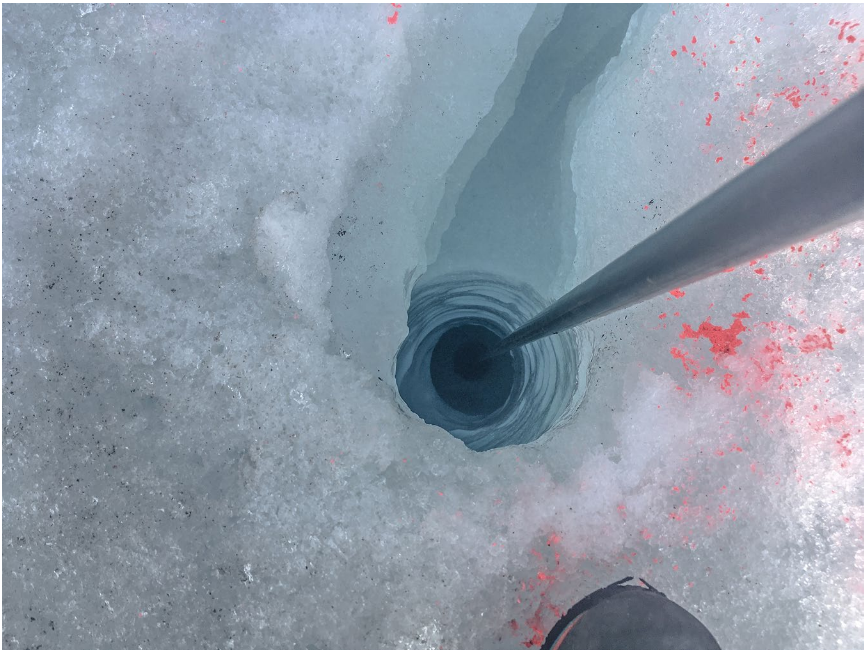

FIG. 13

Donna Haraway's ([1988] 2020) call for "staying with the trouble" and her call for the tentacular: to touch, feel, and test the world with perceptions that go beyond the two-armed, two-eyed, two-eared and one-brained but are instead "many-armed and many-brained" (Haraway 2016). Thus, to be a multitude is to call for diversifying knowledge cultures in ways that promote narratives of care, attention, and sensitivity in sensing not just a "natural world" but also its entanglement with humans and technologies.

This ethnography is of the overlap between the human observer's *umwelt* with that of a sensing system, and the promise is to overcome the objectifying voyeurism of visual observation, instead embracing visuality as a multisensory phenomenon that allows us to "see faithfully from another point of view, even when the other is our own machine" (Haraway [1988] 2020, 583). Remote sensing as an embodied yet distributed phenomenon thus places the observer in multiple and fluid sensory expressions—that is, an expert may go from an acoustic expression of a site to a visual landscape of its anatomy depending on the medium being used for immersion into it. I posit that ethnographic (and artistic) methods can expand themselves by asking what kinds of sensory modalities could be used to communicate the multidimensional aspects of environmental change with care and attention, all the while respecting its enormous complexity as such an unresolved process. Images and sounds

FIG. 13 One of the holes drilled into the glacier to reach its bedrock. Seismic sensors are then lowered and installed at the point of contact between the glacier and the bedrock. *Source*: Mirza.

are powerful and structure our understanding and evolving beliefs about the natural world, forming mental associations that can last for generations. Paying attention to the complex and entangled nature of sound and vision is important for what kinds of images we use to convey knowledge, and ultimately for how societies experience and channel their ecological awareness.

Endnotes

1. The term *firn* comes from Swiss German meaning "yesterday's snow." The firn layer is an intermediate layer of ice in glaciers that protects permafrost.
2. From Gilbert Simondon's philosophy, I use the word indeterminate here to refer to possibilities and potentials in the production and development of an entity or technology, and which can unfold in many probable directions. Not all these possibilities and potentials are always fully realized, and always remain a little incomplete.

ACKNOWLEDGEMENTS

This research would not be possible without Fabien Walter and the Department of Hydraulics, Hydrology and Glaciology at the Swiss Federal Institute of Technology (ETH Zürich) who invited me as a volunteer during their fieldwork on the Rhône Glacier in Switzerland in 2020 as part of my ethnographic research. The generous insights, conversations and data of glaciologists Douglas MacAyeal, Julien Chaput and Dominik Graeff were equally crucial in the development of this research. During my artist residency at the Cité Internationale des Arts in Paris, a collaboration with artist, composer and researcher, Jessica Feldman, produced the score in this article, rendering glaciologist Douglas MacAyeal's original seismic data. I extend my gratitude to all these interlocutors and collaborators.

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