

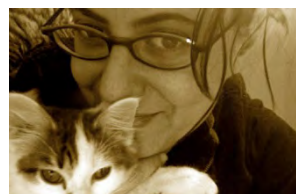
Andrea Wollensak
Judith Goldman
Bridget Baird

Ice Core Modulations: Performative Digital Poetics

Artwork/Paper



Andrea Wollensak
 Connecticut College
 Professor of Art, Director of
 Ammerman Center for Arts &
 Technology
www.conncoll.edu



Judith Goldman
 Assistant Professor of
 English, University of Buffalo,
 NY
judithgo@buffalo.edu



Bridget Baird
 Connecticut College
 Professor Emeritus,
 CS and Math
cs.conncoll.edu/baird **Topic:**
Interactive Digital Poetics,
Data Visualization
Authors:

Abstract:

Antarctic ice core samples embody a rich historical timeline of climate change. Going back as far as 800,000 years, the cores reveal that Antarctic glaciers have trapped the ancient atmosphere in layers of gas bubbles as dateable and distinct as tree rings.

In this inter-disciplinary collaboration, a visual artist, a poet, and a computer scientist collectively develop generative and affective processes that explore and creatively interpret the climate data derived from ice cores, resulting in a performance-based interactive environment.

The work has two main visual-graphic elements, both developed in the Processing visualization language. The first features representations of CO2 bubbles present in the ice core, using atmospheric data of changing CO2 levels through geological time as a driver for the behavior and appearance of the bubbles. The second makes use of various representations of ice cracking and additional features present in the ice core data.

The language of the poetry in this work is culled from research into the material processes through which ice archives the atmosphere and through which, because of global warming, it can become vulnerable to deformation and cracking. This poetry component is both visual and sonic. As the poet performs (reads aloud) the glacier-research poem, textual fragments appear and visually interact within the landscape of evolving and dissolving gaseous and crystalline forms. This on-screen generation of phrases is also driven by ice core data, as is the real-time audio processing of voice, utilizing effects such as reverb and distortion. As the ice's CO2 content increases, the processing of the poet's reading becomes more extreme.



Still image from "Ice Core Modulations"

Contact:

ajwol@conncoll.edu

Keywords: Generative, Visualizing Data, Digital Poetics, Processing

Ice Core Modulations: Performative Digital Poetics

Prof. Andrea Wollensak, MFA

Professor of Art, Director, Ammerman Center for Arts & Technology,

Connecticut College, New London, USA

e-mail: ajwol@conncoll.edu

Prof. Judith Goldman, Ph.D.

Assistant Professor, Poetics Program, Department of English,

University of Buffalo, Buffalo, USA

e-mail: judithgo@buffalo.edu

Prof. Bridget Baird, Ph.D.

Professor Emeritus, Computer Science and Mathematics,

Connecticut College, New London, USA

e-mail: bbbai@conncoll.edu

Abstract

Antarctic ice core samples embody a rich historical timeline of climate change. Going back as far as 800,000 years, the cores reveal that Antarctic glaciers have trapped the ancient atmosphere in layers of gas bubbles as dateable and distinct as tree rings. Such is the point of departure for our interdisciplinary collaboration, in which a visual artist, a poet, and a computer scientist have collectively developed generative and affective processes exploring and creatively interpreting ice core climate data, culminating in the development of a performance-based interactive environment.

Ice Core Modulations has several main visual-graphic elements, all developed in the Processing visualization language. One of the visual elements involves a representation of the CO₂ bubbles present in the ice core, using atmospheric data of changing CO₂ levels through geological time as a driver for the time-based behavior and appearance of the bubbles. Another element feature makes use of various representations of ice cracking present in the ice core data.

The language of the poetry in *Ice Core Modulations* is culled from research into the material processes through which ice archives the atmosphere and through which, because of global warming, it can become vulnerable to deformation and cracking. The poetry component led to the development of the poetic works *Gassigns* and *Fractography*, and includes both visual and sonic elements. As the poet performs, textual fragments appear and visually interact within the landscape of evolving and dissolving gaseous and crystalline forms. This on-screen generation of phrases is also driven by ice core data, as is the real-time audio processing of voice, utilizing effects such as reverb and distortion. As the ice's CO₂ content increases, the processing of the poet's reading becomes more extreme.

1. Background and Motivation

The authors have created independent and collaborative works about the Arctic and Antarctic over the past few years. *Ice Core Modulations* brings together similar interests in a new collaborative and interactive performance work inspired by data found in Antarctic ice core samples.

To begin with, we established a set of core guiding principles that would govern our investigation. These included:

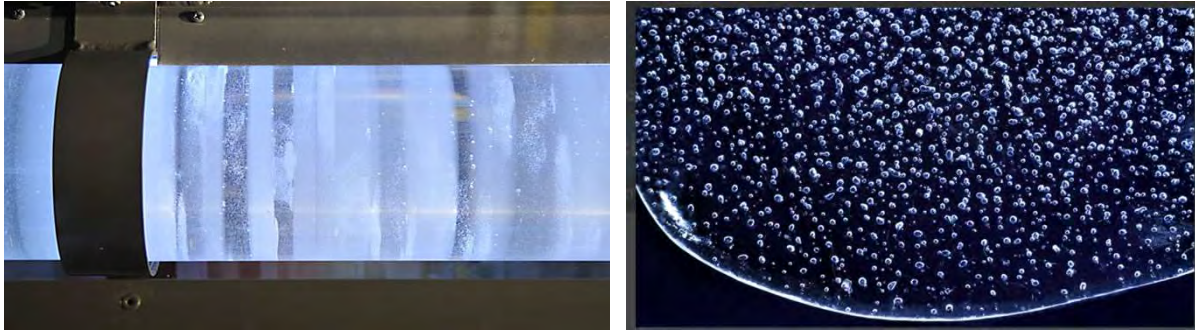
1. Exploring a number of different artistic disciplinary perspectives that would inform how we might visualize environmental data from Antarctic ice core data.
2. Integrating with and being contextually sensitive to poetic texts authored by collaborator Judith Goldman.
3. Supporting a live performance element for the poetic speaker leading to ways in which the spoken poetic text might influence the visual environment.
4. Developing agent-based models to support generative paradigms for the CO₂ ice core sample creative visualizations.
5. Having the performance progress through time in five sections, each with generative sonic and visual elements that reference the environmental changes.

– 2. Research

We decided to use data from the Carbon Dioxide Information Analysis Center (CDIAC) because their documents show a long timeline in ice core records from the last 800,000 years. The data came from Dome C at the Vostok site in the Antarctic and includes a fluctuation between 170 and 400 parts per million by volume (ppmv) that corresponds with conditions of glacial and interglacial periods. Higher volumes indicate glacial decline. “Atmospheric CO₂ levels have increased markedly in industrial times; measurements in 2010 at Cape Grim Tasmania and the South Pole both indicated values of 386 ppmv and are currently increasing at about 2 ppmv/year.” [1]

We met with Dr. Mary Albert, Professor of Engineering at Dartmouth, and Executive Director, U.S. Ice Drilling Program last spring. Dr. Albert summarized that “Ice cores drilled in cold areas of the Greenland and Antarctic Ice Sheets provide high-resolution climate records that are essential for understanding abrupt climate change. The only remaining samples of the atmosphere from past centuries and millennia are contained in bubbles found deep in glacial ice. We are measuring the physical structure, transport properties, and microstructure from ice cores from Greenland and

Antarctica to better understand mechanisms of the trapping of gases in ice cores for improved understanding of abrupt climate changes in the past.” [2] Figures 1 and 2 show imagery of ice core samples and entrapped bubbles viewed close-up.



(figure 1, at left) Ice core close-up. American Museum of Natural History.

(figure 2, on right) Air bubbles in an ice core photo by Eric Wolff / BAS /EPICA

2.1 Poetry Research

The composition of *Gassigns*—a poem inspired by the physical archive of bubbles in the ice core—involved research on the make-up of the atmospheric record entrapped in Antarctic and Alpine glaciers as profiled by ice core sampling, as well as on how ambient gases are incorporated into glacial ice. Further research was done on the global carbon cycle as its dynamics change over geological epochs, especially in terms of its role in generating and terminating Ice Ages. The main materials used here focus on the distortion of the ice record as ice gets older and as it gets closer to warm bedrock (which melts and changes it); in other words, these articles address how cryologists account for these distortions and acknowledge the limitations of ice as data as they build a picture of atmospheric/climate phenomena over time. Such an approach contrasts strongly with the more simplistic framework found in the scientific literature itself but most especially in its representations of an ice core to the larger public as a “perfect archive” or “one-million-page book”.

The composition of *Fractography*—a poem on ice mechanics—involved research in glaciology, engineering, and chemistry/physics literatures on ice as both a brittle and ductile material, with an eye to the massive ablation of ice as ice shelves calve and sea ice melts, due to global warming. Here the focus was in part on the competition and transition between creep and fracture processes in ice (whether ice acts as a liquid or solid), as well as on the initiation and arrest of crack propagation, the modes in and pressures/forces by which cracks crack, and the differing kinds of cracks that are formed. This poem further deals with the fracture of ice at micro and macro levels, taking into consideration how the former affects the latter—understanding a particular glacier’s patterns of recrystallization at the granular level can potentially give important information about very large-scale calving events.

2.2 Audio-Visual Research

The research to develop the audio-visual elements of *Ice Core Modulations* included the evaluation and development of means to process the spoken poetic text as well as the means to process ice-derived sounds. Experimentation was done with different modes of audio processing, utilizing filtering, reverb/delay, and time stretching in order to develop audio that suitably integrated with the spoken poetic text and generative visual elements. Ice sound sources included sounds of melting ice, and sounds recorded via hydrophone underwater microphones such as cracks occurring in frozen lakes. Experiments were also done with how visual text might be granulated and distorted to reflect the chronological elements.

3. Poetic Elements and Processes

The content and form of *Gassigns* and *Fractography* connect to *Ice Core Modulations* on many levels, including specific connections between the sonic and visual processes.

Most obviously, these poems are *non-lyric* poems, meaning they are made of language that does not represent human speech or (psychologized) interiority or subjectivity. A non-lyric poetic mode is fitting for our topic in that it decenters the intentional, humanist subject-as-I. Not only can the poems better reflect the (tragic) irony that the Anthropocene and contemporary climate change are human-authored phenomena not of human design, but they allow the characteristics of ice – its trapping of gases and its mechanics – to take center-stage. Though portrayed in language, ice is not framed from a human point of view; indeed, the poems attempt to approach geological time as well as the carbon cycle as *inhuman* time and to show that our knowledge of the cryosphere, the climate record, and climate change will to some extent always be incomplete and indefinite. Simply by dealing with such extreme landscapes and their phenomena, the poems refuse to pastoralize nature, yet they are also post-pastoral in the sense that they take into account the conditions of the Anthropocene, in which the human has thoroughly interpenetrated the natural, even at the antipodes, in ways largely beyond human control.

Further, the poems make use of very specific non-lyric language – that of highly specialized scientific discourses. They thus overcome normative disciplinary divisions, to stage an encounter between scientific terminology and knowledge and aesthetic practice, doing so through a poetic treatment of scientific texts. This treatment involves, in part, foregrounding the inhuman but nonetheless affecting materiality of their language. Through selection and recombination, the poems make the most of science's unlikely potential for rhythm and rhyme, drawing attention to scientific texts as a part of an apparatus of representation and mediation, while at the same time faithfully communicating the entities and processes they describe. This amplified, experiential presentation of scientific texts is meant to face the challenge of making scientific knowledge relatable and graspable to non-specialists and specialists alike.

Yet precisely in their use of scientific discourse, the poems seek to go (impossibly) beyond that discourse, to establish a relationship of radical mimesis with that language's referent, the natural world. In this sense, while the poems may describe the cryosphere, they attempt at the same time,

through the verbal medium, to enact or perform it, alongside it, the human-driven, accelerated chaos of its current flows. In their proposed mimicry of ice worlds, the poems use language as a material to carry or transmit affect, such that their human audience might take on the affect of geophysical processes.

The formal attributes and thematic content of the poetry here have also been chosen in light of poems' status as a component in a larger generative artwork. These poems share with generative art a non-subjective mode of composition. Further, the attention to lively, suggestive scientific jargon as well as to the sonic and rhythmic patterns within the poems allows their phrases to be used as units, and thus to be broken down modularly and submitted to randomizing algorithmic and data-indexed processes of selection, as well as to dynamic visual treatment. Given the focus on climate change-related phenomena in the poem, both the text and vocal performance gain a great deal from audio and visual processing meant to degrade, distort, and blur this material. This larger project's narrative follows a trajectory of increasing densification and chaos as the piece unfolds, in accord with the rising CO₂ levels found in the most recent ice in the ice cores. A further interactive, mimetic dimension among the media in the piece involves how the data drives the audio processing of voice, while the voice will also trigger changes in the visual environment. This feedback loop reflects a number of the global natural processes, for instance, how global warming increases CO₂ levels, while CO₂ levels increase warming.

3.1 Excerpt from *Fractography*

linear elastic fracture mechanics

balance in crack propagation

tensile fracture stress:

dislocation pile-up nucleates crack at grain boundary

interatomic bonding overcome by stresses at crack tip

crack grows in its own plane, progressed by stick-slip

direct crack path:

crack propagates in a self-similar manner

unstable (rapid) growth of a single flaw,

perpendicular to direction of maximum tension

opening, sliding, or tearing crack

crack as infinitely narrow hole

crack tip relative to crack body

cracks propagate to a free surface

thermal cracks from thermal shock

crack growth and crack arrest

long-wave cracks; catastrophic crack propagation

onset of unstable rapid cracking

driving energy drops: crack stops

inelastic zone at crack tip

softening active ahead of the crack

tensile microcracks in a compressive stress field

critical crack density

interaction of small feather fractures

weakened shear zone

local edge fractures (spalls)

ice edge shape evolves: result of local failure processes

edge geometry

contact forces redistributed:

spall has been expelled

tensile stresses separate crack faces;

compressive loading causes contact

grain boundaries are weak in shear

crack tries to slide or shear along the crack length

opening-mode cracks curve: free ends contact

sliding parent crack: plates bend and break

radial bending cracks grow from center

ice plate decomposed into wedges

energy released dissipated

by creating crack surface: not plastic work

ice plate may fail by a conic crack under the load

or partial crack as a line spring in the crack line

4. Visual/Sonic Elements and Generative Processes

The visual environment of *Ice Core Modulations* includes a continually modulating assemblage of generative forms and shifting colors as a backdrop from which foreground oval-shaped forms emerge and move outwards, towards the viewer and out of the visual field. The oval forms represent and are meant to connote the CO₂ bubbles as they are liberated from the ice, becoming data as well as historical narrative. Excerpts from the two poems continually appear and are juxtaposed with the oval forms. The poetic fragments exhibit two principal behaviors, either forming in the back of the visual environment and moving out towards and past the viewer, or emerging from abstract granular noise and coalescing into recognizable text phrases before fading away. The poetic visual gestures make use of randomness and ice core data to govern when they appear and how they move.

The primary driver for the time-based behavior and appearance of the oval forms is the changing CO₂ levels over the vast span of geological time. Notably, much of the CO₂ data does not vary greatly until quite recently. In *Ice Core Modulations* these changes start to happen in section 2. The CO₂ data has a huge upswing in the quantity of gas recorded in recent time (1865-2015), which ultimately results in the chaos and density exhibited in the final, fifth section of the work. The overall timeline serves as the background for the reading and recorded processed poetry. The overall expression of the performance comes through the visual densifications, the poetry, and the volume and dense layering of audio and increase of visual forms.

The sonic component of the environment includes both recorded vocal and environmental sounds as well as live spoken poetry. The recorded environmental sounds (e.g., melting ice, cracks occurring in frozen lakes) were processed using compression, granular synthesis, reverberation and low pass resonant filters. Recorded vocal elements are generatively processed in real-time through layering, reverberation and echoing. Live spoken poetry is highlighted in the sonic environment through real-time interaction (affecting sonic/visual elements) and eventually creating its own modes of distortion.

Generative elements govern the entire piece. Although operating under an algorithmic structure and timeline, randomness occurs in most of the visual and sonic elements including the shape and motion of blue ice, the location and appearance of CO₂ bubbles, the order, size, movement and distortion of poetic phrases in the visual field, the audio processing of both live and recorded audio (e.g., readings from poems), and the chaotic culmination of the work.

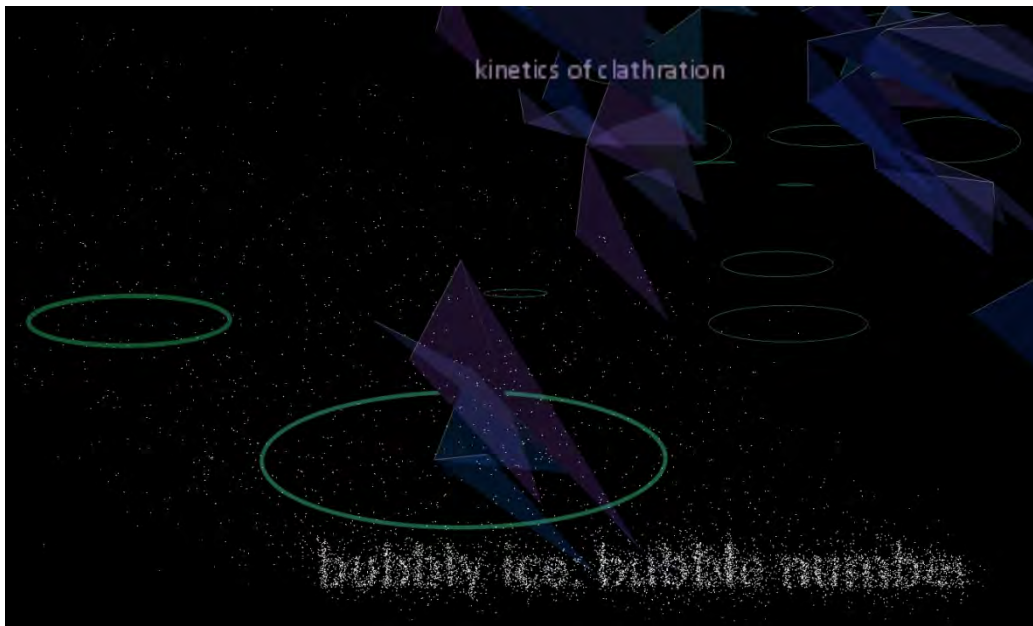
– 5. Performative Scenes/Sections

The whole performance, as interactive poetry reading, is divided into five sections, each of which suggests a segment of CO₂ data in a linear timeline, beginning with early data and ending with current data. All five sections narrate the increase in CO₂ levels, conveyed, for instance, in the visual field, through color and density. In the following text, each of the sections is briefly introduced.

Section one is an introduction to the 'characters' in the work. Overall, this section has a low density of forms and sounds. Blue ice forms appear small with minimal CO₂ oval forms. The processed environmental sounds eventually fade out as generative spoken text and visual text become the figure.

In the longer section two, the *Gassigns* poem is read. Generative CO₂ forms and blue ice forms appear and move faster within the space. Phrases from the poem appear visually in generatively processed typographic form. Typographic visual phrases also appear in granulated, generatively

processed form (figure 3). Environmental audio and audio segments of poem are also generatively processed, providing sonic layering.



(figure 3) Section two environment with ice cracking,
CO₂ oval forms, and granulated poetic phrases.

In the short section three, which is similar to section one, CO₂ forms continue to move at a faster pace, with increase of blue/green ice forms. Environmental sounds are heard and overall the feeling of movement and density increases.

In section four, parts of the poem *Fractography* are read with live processing, CO₂ forms appear in different sizes and move faster, while the colors of the ice forms shift to the warmer spectrum. Sonic components of processed environmental sounds and recorded processed voice are no longer linked to visuals.

In the last section, CO₂ forms are dense, ice forms are moving faster and are light and warm in color. Multiple tracks of recorded and heavily processed phrases of *Fractography* are re-introduced, with higher volume environmental tracks and live reading of rhetorical address. The pace and chaos of this section greatly increases as the piece culminates and ends.

7. Summary and Future Directions

Ice Core Modulations arose from a set of guiding principles, noted in the Introduction, that involve connections between the narratives of environmental change encoded in ice core CO₂ data and audio-visual, sonic and poetic elements inspired by the data. The collaborative intent of *Ice Core Modulations* project was to allow for interdisciplinary synergy between a creative team spanning poetry, computer science, and visual art, expanding the technological and creative means by which the CO₂ data could be conveyed and expressed. This first iteration of the project served as a valuable test-bed for our concepts and techniques and has helped us determine future research and

conceptual directions. The collaboration is in its early stages, and next steps include travelling to Greenland next summer to collect audio and visual recordings to incorporate into this work. We also plan to submit a proposal to the National Science Foundation Antarctic Artists and Writers Program in 2016.

Notes

[1] <http://cdiac.ornl.gov>

[2] <http://engineering.dartmouth.edu/research/ice-core-interpretation/>

References

- Adolph, A.C., and M.R. Albert, 2014. Gas Diffusivity and Permeability through the Firn Column at Summit, Greenland: Measurements and Comparison to Microstructural Properties. *The Cryosphere*, v. 8, p. 319-328.
- Baird, B., Izmirli, O., Wollensak, A., (2011): *DEEP/PLACE: site-based immersive history*, ISEA, Proceedings of the International Symposium of Electronic Arts, Istanbul, Turkey.
- Baird, B., Charles Hartman, C., Izmirli, O., Kreiger, A., Wollensak, A., (2008): *One Thing Leads to Another (Interdisciplinary Antecedent/Consequent Explorations)*, Proceedings of the Eleventh Biennial Arts and Technology Symposium at Connecticut College.

Bereiter, B. et al. "Diffusive equilibration of N₂, O₂, and CO₂ mixing ratios in a 1.5-million-years-old ice core." *The Cryosphere* 8 (2014). 245-256.

- Pearson, Matt, *Generative Art: A Practical Guide Using Processing*, (2011), Manning Publications, Shelter Island, NY.
- Reas, Casey and Ben Fry. 2007. *Processing. A Programming Handbook for Visual Designers*. Cambridge, MA: MIT Press
- Schulson, Erland M. and Duval, Paul. *Creep and Fracture of Ice*. Cambridge: Cambridge University Press, 2009.
- Schwarzschild, Bertram. "Carbon Dioxide drove the ending of the last glacial epoch." *Physics Today*.

June 2012. 16-18.

- Shiffman, Daniel. 2012. *The Nature of Code: Simulating Natural Systems with Processing*