APPENDIX

These additional materials serve to give greater context to my piece *Currents*, however they are not essential to the understanding of the work.

The first section is a philosophical overview and informally discusses the general topics and questions addressed in *Currents*
(artists and climate change, sonification, data).

The second section is more theoretical and details the processes by which the music of *Currents* was sonified (initial research questions, sonification methods, historical/cultural context of the weather events).

PART 1: CONTEXT

ARTISTS IN AN ERA OF CLIMATE CHANGE

In a 2011 Julliard commencement speech, the composer John Adams cleverly remarked that "the wonderful, astonishing truth is that the arts are utterly useless. You can't eat music or poetry or dance. You can't drive your car on a sonnet or wear it on your back to shield you from the elements."[1] Of course, Adams later counters this glib remark ("what we artists offer is one of the few things that make human life meaningful"),[2] but his assertion still questions the value of art against the necessities of basic survival. In a time where human beings face the existential threats contained in the looming issues of climate change, it is worth re-evaluating the role of the artist and what perhaps artists can offer.

In September 2019, I became a vegetarian literally overnight. My sister invited my wife and I to see a talk by the author Jonathan Safran Foer. He was discussing his new book *We Are the Weather: Saving the Planet Begins at Breakfast* to a well attended audience at the University of Michigan. Despite my wealth of prior knowledge from my years of interest in weather and climate change (I myself took an "Extreme Weather" course at this very same college years ago), this event was a transformative experience that not only radically altered my thinking on the issue, but also affected my personal choices and actions. My wife and I left that talk as committed vegetarians, which was no easy feat for two meat lovers such as ourselves. Safran Foer's persuasive strategy was innovative, choosing to go beyond rolling over the talking

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[1] John Adams, "Julliard Commencement Speech," *NewMusicBox*, May 23, 2011, https://nmbx.newmusicusa.org/juilliard-commencement-speech/

[2] Ibid.

points and statistics of animal farming being one of the main expenders of greenhouse gases. He also unpacked the human feelings tangled up in resisting desire (i.e. craving meat) and flipped the conversation to be about the powerful feeling that comes with having personal agency against an insurmountable challenge. Safran Foer, who is not a scientist by any means, was able to push my knowledge (or more accurately, my feelings and actions) about climate change in the space of an hour. In one of the most compelling passages in his book, Safran Foer discusses the distinction between "knowing" and "believing":

> Intellectually accepting the truth isn't virtuous in and of itself. And it won't save us. As a child, I was often told "you know better" when I did something I shouldn't have done. *Knowing* was the difference between a mistake and an offense. If we accept a factual reality (that we are destroying the planet), but are unable to *believe* it, we are no better than those who deny the existence of human-caused climate change…And when the future distinguishes between these two kinds of denial, which will appear to be a grave error and which an unforgivable crime?[3]

The role of the artist, although seemingly meaningless in the face of more practical roles such as scientists and activists, has the power to persuade individuals not just how to think differently, but how to *feel* differently about climate change through their storytelling and crafting of emotional responses. They have the power to foster this leap from knowing to believing, a gift that Safran Foer, a writer, an *artist*, gifted me. It is not merely facts that have the power to persuade us. It is the narrative, the story. Even climate scientists acknowledge this gap between knowing and believing, as well as the lack of communication that can result. Marx and Weber note:

> Technical experts and academics tend to rely more heavily on analytic processing in their definition and evaluation of possible risks, while politicians, end-user stake-holders, and the general public rely more heavily on experiential/affective processing.

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[3] Jonathan Safran Foer, *We Are The Weather: Saving The Planet Begins At Breakfast* (New York: Farrar, Straus, and Giroux, 2019), 21.

> This is one reason why often, climate science information does not readily feed into decision makers' existing decision models and procedures.[4]

Specifically, musicians and composers have a large role to play in this climate crisis. "Music is no alternative to environmental activism or climate science or direct exposure to melting ice caps, rising seas, and cataclysmic winds, but it can compose climate-change sensations that directly affect our listening, feeling, and thinking."[5]

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[4] Sabine M. Marx and Elke U. Weber, "Decision Making under Climate Uncertainty: The Power of Understanding Judgment and Decision Processes," in *Climate Change in the Great Lakes Region: Navigating an Uncertain Future,* ed. Thomas Dietz and David Bidwell (East Lansing: Michigan State University Press, 2011), 103.

[5] Dianne Chisholm, "Shaping an Ear for Climate Change: The Silarjuapomorphizing Music of Alaskan Composer John Luther Adams," *Environmental Humanities* 8, no. 2 (November 2016): 175.

THE LANDSCAPE OF COMPOSERS

The relationship between composers and weather shares a long history, with two of the most beloved examples in the Western canon being Vivaldi's *The Four Seasons* (1725) and the fourth movement of Beethoven's *Pastoral Symphony* (1808). Aplin and Williams provide a sweeping summary of orchestral works depicting meteorological events, illuminating the particular fascination of composers with storm events in their music.[6] Spitzer and Zaslaw argue that the fourth act of Marin Marais' *Alcione* (1706) provided an "enduring model" for musical *tempêtes* (storms) with its use of "tirades, tremolos, rolling timpani, and a double bass."[7] Blowing wind also emerges as a theme in several compositions, an early example being the "Western Wind" masses of Taverner, Tye, and Sheppard that utilize a cantus firmus from the anonymous sixteenth century song "Westron Wynde."[8] However, the work of several modern day composers speaks more specifically to the burgeoning climate crisis and the shifting weather patterns on our planet.

Perhaps the most well known and critically acclaimed musician working in this vein is John Luther Adams, a composer who "places our hearing at the forefront of climate change."[9] Informed by his experience as a long time resident in the natural beauty of Alaska (he has since

[6] Karen L. Aplin and Paul D. Williams, "Meteorological Phenomena in Western Classical Orchestral Music," *Weather* 66, no. 11 (November 2011): 300-306.
[7] John Spitzer and Neal Zaslaw, *Birth of the Orchestra: History of an Institution, 1650-1815* (Oxford: Oxford University Press, 2005), 488.
[8] Nigel Davison, "The 'Western Wind' Masses," *The Musical Quarterly* 57, no. 3 (1971): 427-443.
[9] Chisholm, 174.

moved),[10] he has created several climate-related works including the sound and light installation *The Place Where You Go To Listen* (2006), the Pulitzer Prize-winning piece *Become Ocean* (2013) and his most recent work *Become Desert* (2019). In explaining his philosophy and approach, Adams draws from ideas relating to ecology (which he defines as "the totality of patterns and the larger systems they create"[11]) and relates them to the process of musical elements (melody, timbre, etc.) coming together to form a totality of sound. Adams argues:

> The central truth of ecology is that everything in this world is connected to everything else. The great challenge now facing the human species is to live by this truth. We must reintegrate our fragmented consciousness and learn to live in harmony with the larger patterns of life on earth, or we risk our own extinction. As a composer it is my belief that music can contribute to the awakening of our ecological understanding. By deepening our awareness of our connections to the earth, music can provide a sounding model for the renewal of human consciousness and culture.[12]

While John Luther Adams' music engages directly with the landscape of the natural world to engage with the issues of weather and climate change, my work *Currents* specifically works with data to represent this same issue. As a brief summary, below is a list of other contemporary composers and artists who exemplify the methodology of utilizing climate/weather data to create music:

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[10] As of 2015, he resides between New York City and the Sonoran Desert. Tom Service, "John Luther Adams: A Force of Nature," *The Guardian*, July 2, 2015, https://www.theguardian.com/music/musicblog/2015/jul/02/john-luther-adams-music-across-the-distance-southbank

[11] John Luther Adams, *The Place Where You Go To Listen: In Search of an Ecology of Music* (Middletown, CT: Wesleyan University Press, 2009), 1.

[12] Ibid.

- Matthew Burtner, a music composition professor at the University of Virgina, has an entire body of work dedicated to climate change and the environment that he calls "ecoacoustic pieces." Two notable examples are his climate change opera *Auksalaq* (2012), which was co-created with Scott Deal (Professor of Music, Indiana University-Purdue University Indianapolis) and performed telematically by remote ensembles across the world, and *Spectral Arctic Ice Triangulations* (2012), which blends field recordings of a hydrophone suspended underneath a polar ice cap with a live percussion ensemble playing instruments lowered into tubs of water.
- Andrea Polli, an environmental artist and professor at the University of New Mexico, has created several public art installations that integrate sound, technology, and data to depict weather and climate data. *N-point* pairs sonified weather data from the North Pole with timelapse videos taken from webcams in the Arctic. *Atmospherics/Weather Works, A Spatialized Meteorological Data Sonification Project* works with data taken from two major storms that hit the Eastern U.S. in 1979 and 1991. Six data points from the storms (pressure, water vapor, humidity, dew point, temperature, wind speed) are paired with various sound sources broadcast through a 16 channel speaker system.
- Katie Paterson, a visual artist originally from Glasgow, Scotland, created the work *Langjökull, Snæfellsjökull, Solheimajökull* by recording the sound of three Icelandic glaciers, pressing these recordings into records made of frozen meltwater from these same glaciers, and playing the records on a turntable until they melted.

- Judy Twedt, an Interdisciplinary Individual Ph.D. student at the University of Washington, used satellite Arctic Sea ice level data to create *Arctic Sea Ice,* a solo piano work where the left hand notes represent the passage of seasons and the right hand notes correspond to the percentage of ice cover.
- Mark Ballora and Jenni Evans, two professors at Penn State University, have released videos that take four pieces of hurricane data (air pressure, longitude, latitude, symmetry) and represent them with sound. Their approach is more practical and less artistic, arguing that creating audible forms of hurricane data can make it easier for the data itself to be communicated.
- The ClimateMusic Project, founded by Stephan Crawford, has commissioned a number of pieces (*Climate, Icarus in Flight, What if we?*) exploring the relationship between climate change data and music.
- Scott St. George and Daniel Crawford, a geology professor and a music student (respectively) at the University of Minnesota, collaborated to produce two works (one for solo cello, one for string quartet) that translates 133 years of global temperature data into music. The temperature data was converted to pitch information, which was then notated with written music for the instruments.

SONIFICATION DEFINED

In discussing his work *The Place Where You Go To Listen*, a sound/light installation that depicts live natural activity in Alaska (geomagnetic, astronomical, seismological, and meteorological data), John Luther Adams gives us a basic working definition of sonification: "the process of mapping data with *some other meaning* into sound."[13] The familiar, everyday examples of this include the clicking of a Geiger counter, the beep of a heart monitor, the pinging of a sonar wave, and the ticking of a clock to mark the passage of time. However, these examples are quite literal in their usage of the data. Although there is perhaps some creative choice as to what sounds a heart rate monitor produces, the role of the device is simply practical. It authentically and directly communicates data to the best of its ability, and any attempt to map "some other meaning" onto the sound would most likely impede the device's ability to communicate a patient's heart rate data to a nurse nearby. But Adams is pointing us towards a definition of sonification that is more interpretative, creative, and (perhaps) artistic. To be more specific with our definition of sonification, we will expand on Adams' definition by borrowing Gresham-Lancaster and Sinclair's breakdown of five types of sonification:[14]

- Auditory Icons, such as a computer's trash bin making a sound when you click on it
- Earcons, such as the announcement chimes on a PA system

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[13] Luther Adams, 113.

[14] Scot Gresham-Lancaster and Peter Sinclair, "Sonification and Acoustic Environments," *Leonardo Music Journal* 22 (2012): 68.

- Mapping-Based Sonification, which is "data that directly modifies parameters of a sound" such as a pulse-oximter correlating a patient's blood oxygen saturation to pitch and their heart rate to tempo
- Remapping, which is "information encoded as a perturbation of parameters in an audio source" (and probably more of what Adams was trying to define)[15]
- Audification, which is a "direct transposition or transduction of a signal into the audio domain" such as electrical impulses in a person's body being made audible

It is also useful to think about the functions that these types of sonification can provide. A short list of the functions of sonification include: creating alerts, notifications, status monitoring systems, and data exploration systems. Sonification can also function in the domains of entertainment, sports, and exercise.[16] One more important thing to note before moving on: sonification can refer equally to the translation of data into acousmatic sound (ex: fixed media works, electronic soundscapes) or the translation of data into notated music. Most of my examples in the next few sections navigate more towards the acousmatic aspects of sound, however they can equally apply to notated music.[17]

The use of visuals is the most ubiquitous method to convey data; it is reasonable for the average person to treat the word "data" as synonymous with "visual data" based on the amount of visual information we receive in our world. The process of sonification offers unique

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[15] This is the category I believe my Master's Thesis work Currents falls under. My work seeks to remap, or project other meanings (musical, artistic, historical), onto sound created from weather data.
[16] Thomas Hermann, Andy Hunt, and John G. Neuhoff (eds.), *The Sonification Handbook* (Berlin: Logos Verlag, 2011), 12-15.
[17] As an aside: there is a philosophical question of where the sonification begins. Is notated music on a page a "sonification" even though it is not actually producing sound? Is it only "sonified" when live instruments perform it? For my work *Currents*, I am treating notated music as a valid form of "sonification" in and of itself.

strengths to data communication. Gresham-Lancaster and Sinclair offer that sonification can function as a "direct meditation" that "is no longer a representation but rather a process that is part of the dynamic of the acoustic environment itself." They also suggest that "there are resonances with the cultural memories of musics and life experiences of sound environments. These resonances are embedded in any sounding that is happening, and we are listening all the time." Finally, they offer that sonification, and more specifically audification, "can render audible elements of the environment that would otherwise be imperceptible due to their scale (e.g. meteorological or seismic data)."[18] Ballora and Evans point out that while "our eyes are good at detecting static properties, like color, size, texture…our ears are better at sensing properties that change and fluctuate [such as pitch and rhythm]." They also note that the ear is able to interpret "multiple patterns simultaneously, which is what we do when we appreciate the interlocking parts in a complex piece of music" as well as the fact that "sound is also processed more quickly and more viscerally than visuals." Finally, they argue that sonification can provide greater universal access to data for people with cognitive disabilities, visual impairments, and lack of access to technology (ex: limited phone bandwidth, only have access to radio, etc).[19] Polli specifically discusses the sonification of meteorological data and notes that the process "could emphasize aspects of the data not apparent in visualizations, allowing meteorologists to detect new patters and structures, particularly those that unfold over time."[20] Echoing Gresham-Lancaster and Sinclair's thoughts on cultural memory, she argues

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[18] Gresham-Lancaster, 69.

[19] Mark Ballora and Jenni Evans, "Turning Hurricanes into Music: Can Listening to Storms Help Us Understand Them Better?" *The Conversation* December 4, 2017, http://theconversation.com/turning-hurricanes-into-music-can-listening-to-storms-help-us-understand-them-better-88203

[20] Andrea Polli, "Atmospherics/Weather Works, A Multi-Channel Storm Sonification Project," *International Conference on Auditory Display* (2004): 1.

that sound's temporal aspect makes it a better-suited vessel to convey narrative and emotion than visual imagery. Polli also points to the physical and visceral properties of sound, which more closely emulates the experience of being in an actual meteorological event. Finally, she shares that weather is often depicted using two-dimensional imagery but that weather, as well as sound itself, are three-dimensional mediums. These examples suggest that certain types of complex data, like hurricane strength, may be communicated better through sound instead of sight. Not only does this serve practical, scientific purposes, but can be used (as shown in this thesis) towards artistic, creative, social, and political ends as well. Just as Jonathan Safran Foer's thoughts as a writer gives greater cognitive, emotional, and narrative depth to the climate crisis, Polli argues for the application of a sound artist's talents in creating new meanings behind data:

> I am interested in the artistic creation of new languages of data interpretation. As individuals and groups are faced with the interpretation of more and more large data sets, a language or series of languages for communicating this mass of data needs to evolve. Through an effective sonification, data interpreted as sound can communicate emotional content or feeling, and I believe an emotional connection with data could serve as a memory aid and increase the human understanding of the forces at work behind the data.[21]

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[21] Polli, 2.

SONIFICATION AND DATA IN PRACTICE [PART 1]

What types of technology and software are most conducive to the sonification process? How does one go about accessing data in the first place to *be* sonified? What are the best practices for sonification and what are its limitations? This section broadly address these questions, with the intent that the themes and issues discussed here periodically emerge during the analysis and discussion of my work *Currents.*

Tsuchiya, Freeman, and Lerner provide a short overview of the existing models and frameworks for data sonification. They first differentiate between two models of sonification: Parameter Mapping Sonification (PMSon), where each application "requires a new mapping specification for each application," and Model-Based Sonification (MBS), where models are created using a "design-once-use-many" philosophy.[22] From there, they list various softwares and programming languages that have been used for sonification frameworks (JavaScript, Pure Data, SuperCollider, Csound, Max/MSP). They also discuss various data visualization networks that, while not necessarily used for sonification, provide frameworks for accessing and working with data (Protovis, D3.JS, RAW). They conclude their overview by listing specific examples of work sonification programs created using these tools (Sonification Sandbox, Interactive Sonification Toolkit, SonART, SonData, and their own invention DataToMusic API).

[22] Takahiko Tsuchiya, Jason Freeman, and Lee W. Lerner, "Data-To-Music API: Real-Time Data-Agnostic Sonification with Musical Structure Models," *International Conference on Auditory Display* (2015): 1.

To be clear: these models and frameworks have more to do with the aspects of *sound production* and less to do with the acquisition of *data* in the first place. To that end, what mechanisms are in place for acquiring the data itself? In short, it depends. Gathering data about the color of each pixel in an image file can be a vastly different experience from gathering data about a particular Twitter hashtag, mostly due to the potentially different software applications needed to access the data. And of course, there is nothing from stopping you from sitting down and manually punching out your own data table in a program "by hand." This obviously requires tedious amounts of unnecessary time and patience. Rather than reinvent the wheel, I will discuss more efficient (or perhaps, *automated*) computing methods for accessing large datasets.

One common method is to access an API, or an Application Program Interface. API's can be thought of as the building blocks that programmers use to build applications. Once built, API's are a means to get software components to interact and collaborate with each other.[23] API's can quickly and easily give access to a website's data and are invaluable sources for any sonification project. Another method of data acquisition is a JSON file, or a JavaScript Object Notation file. JSON is an open file format used to store, encode, and transfer data in a text format. They act as databases, storing data in rows and indexes that allow the user to call up specific values or data points simply and efficiently. Whether you access data through an API or a JSON, there is still the issue of importing the data into your sonification software of choice

[23] Here is a fast example: Let's say I have a website and I want to display a custom map with my own content/imagery inside of it. I could build a program to make a map from scratch, or I could use the Google Maps JavaScript API as a toolkit to build it. Once I have used Google's API, it collaborates with the program used to run my website and allow me to embed my custom map on my website. Another analogy commonly used: In a restaurant, you don't acquire food directly from the kitchen. The food from the kitchen (data on a website) comes to you through your interaction with a waiter (the API).

(ex: how is Max/MSP going to talk to this API or read this JSON file?), as well as parsing out the data (ex: once Max/MSP has accessed this weather dataset, how can you extract a particular data points you need, such as a temperature reading?). This often requires the additional hoop of another programming language like JavaScript, but it is hard to know without knowledge of the specific software being used. Here I can only speak to my specific experiences using Max/MSP, which I will address later.

The process of sonification is certainly not without its challenges and limitations, with one of the greatest being the process of accessing data I just described above. From my own experience, there seems to be no clear methodology for gathering and parsing data with any of the current software tools available and the process can be endlessly laborious and frustrating. During the creation of Andrea Polli's work *Atmospherics/Weather Works, A Spatialized Meteorological Data Sonification Project*, she details the process for creating two custom pieces of software to sonify the data for her project (one was created by two climate scientists to export the data, another was created by a programmer in Max/MSP to sonify it). Although she only hints at the labor intensiveness of this process (at one point, she refers to it as a "daunting task"), it is clearly quite difficult to have to use a two-step process with two different pieces of custom software to separately acquire *then* sonify the data. This is by far one of the greatest limitations for sonifying data using computer software, and perhaps in the future the developers for music programming languages (Max, Super Collider, etc) will find ways to streamline this process.

SONIFICATION AND DATA IN PRACTICE [PART 2]

Once the data is gathered and parsed, there are additional challenges in working with data in the sonification process. One particular challenge is scaling, or calibrating the parameters of sonification in order to effectively convey the data to the listener. Gresham-Lancaster and Sinclair note the importance of this step, remarking that “predictions and manipulation of scaling are integral parts of the refinements needed to make the pieces work.”[24] As an example: If I am sonifying temperature data into pitch, how much should one degree of temperature change affect the pitch? Does one degree equal a half step? A whole step? More? Less? If we *under* scale the data, the fluctuations in sound might be too gradual or minute for the listener to hear any difference; if we over scale the data, we might create extremes in the data that might, for example, send some pitch data points beyond the limit of human hearing (example 1).

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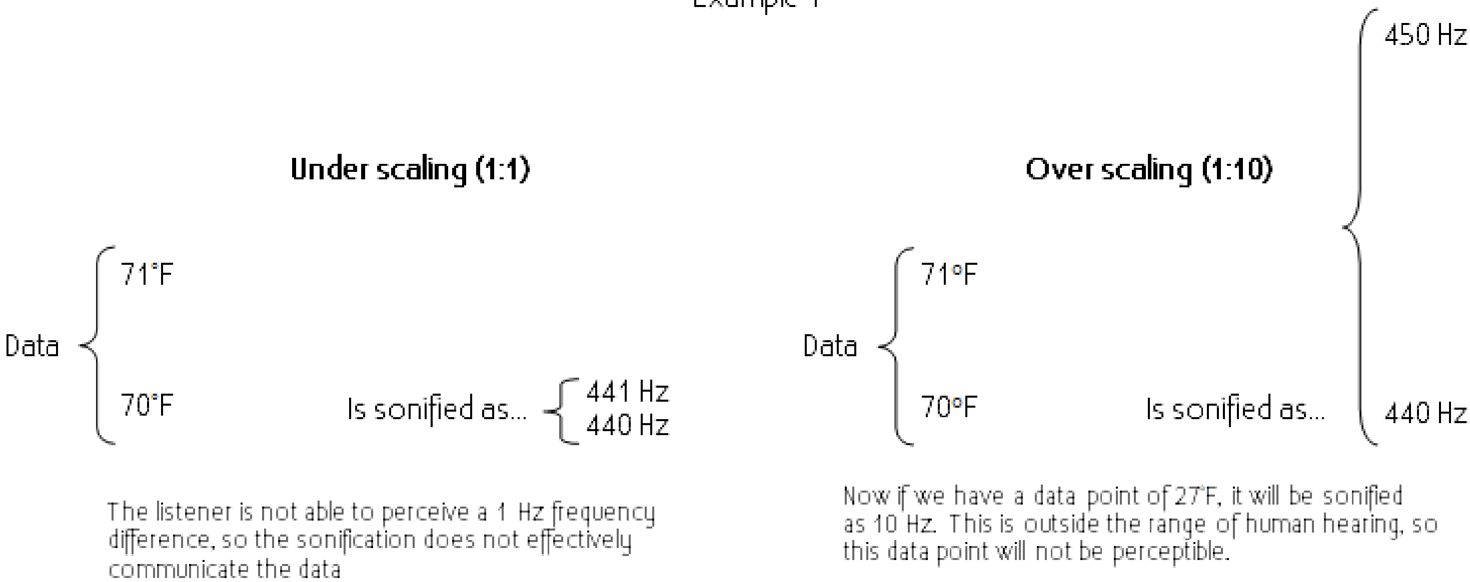
[24] Gresham-Lancaster, 69.

Example 1



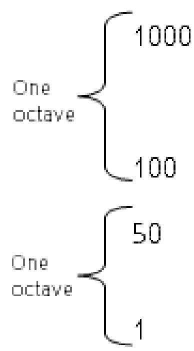
There are ways to manage scaling, such as creating algorithms or equations that look at the extreme outliers of the data and adjust parameters accordingly. Picking the median data point and structuring your scaling around that value is also helpful. Another solution is to create what I call “parameter bands,” which scales the data in different ratios based on how wide the data set is. As an example, let’s say I have a collection of data that mostly falls between the numbers 1 and 50. A few data points, however, leap up to the numbers 100, 200, or even 1000. If I scale all of my data to these outliers, the change from 1 to 10 might become imperceptible. If I scale all of my data to align better to my 1 to 50 range, these outlying values might sonify in some extreme ways (Example 2). Instead, I could create one “parameter band” that encapsulates the numbers 1 through 50 (let’s say that sonifies a one octave scale range) and then another “parameter band” that encapsulates the numbers 100 through 1000 (let’s say that sonifies another octave range). This way, all of my sonified pitches fall within a two octave range even though the data is much “wider” than that (Example 3).

Example 2

If most of our data lies between 1 and 50, there will be very little change to our sonified sounds.

To get to the data point 1000, we would need to sonify up to 20 octaves. This is beyond the range of human hearing.

Example 3



Parameter bands. Not all data ranges are treated equally, but the sonification will be much more even as a result.

These issues with scaling are perhaps most difficult in live situations, where data is being collected in real time. In these situations, it might be helpful to allow for live calibration of the parameters in the sonification program using sliders or knobs to adjust the scaling of the data.

Another general issue with sonification is the tension between free musical interpretation and strict adherence to the data. On the one hand, we could take the last 100 years of temperature data and sonify it with written pitches (higher temperature = higher pitch) for a solo instrument to play. The benefit is that the listener would perceive the relationship between the data and the sounds to be exceptionally clear. The drawback is that the music has the risk of coming across as an exercise, too tied to the data to be musical at all. Furthermore, what if the data creates an unfulfilling melody? How much of the sonified data is the composer ethically allowed to change to achieve a musical result? On the other hand, we could take the last 100 years of six different data points (ex: temperature, cloud cover, ice cover, CO2 emissions, etc) and sonify them with six different musical elements (ex: pitch, tempo, dynamics, timbre, etc) for a solo instrument to play. The benefit would be a rich, musical work with contrast, energy, and complexity. The drawback is that the listener might struggle to hear the relationship between the data and the sounds that are sonifying it. Gresham-Lancaster and Sinclair discuss this phenomenon, noting a situation where "one cannot understand [the work] by listening to the music, and the fact that it is driven by this data is not apparent unless one is informed by the posters [explaining the work]."[25] These two scenarios are extremes, but it illustrates that throughout the process of sonification, the composer has to decide how much to strictly adhere to the data and how much to inject their own musical adjustments. There are no easy guidelines of when the composer should assert their musical identity, and often the decision-making can be difficult and involve a great amount of trial and error. As a starting exercise, it might assist the composer to come up with a single sound parameter the data will

[25] Gresham-Lancaster, 69.

control (ex: pitch), sonify the data, then revise the sonification by picking two musical parameters (ex: rhythm and dynamics) that will be freely interpreted with what has already been sonified.

Finally, there are ethical and philosophical issues surrounding "big data" that demand mentioning. There have been many recent concerns over the privacy and security of data, most evident in the scandals committed by technology corporations and other large institutions (i.e. Facebook and Cambridge Analytica, the NSA and the Edward Snowden scandal). While a composer certainly does not share the same level of power as a large institution, there is a certain amount of power that comes assigned to the role of a data interpreter. How ethical is it for a composer to use this data for their own purposes? What kinds of data should and shouldn't the composer have access to as not to violate privacy concerns? On another ethical note, even though an artist has the unique opportunity to craft a powerful narrative within the data, it is (surprisingly) easy to view the data from a place of detachment and distance. When working with data that can be incredibly sensitive (for example, the number of deaths in an extreme weather event), the composer has a responsibility to determine the appropriate way to honor this data in a way that doesn't trivialize, disengage, or isolate. Although these philosophical questions about data are too heavy for a single artist to bear, they are nonetheless unavoidable and require an artist's attention of they decide to partake in the process of sonifying it.

PART 2: CURRENTS

GUIDING QUESTIONS

EXPERIMENTS AND TESTS

MVT. 1: ACOUSMATIC SONIFICATION

MVT 2-6: NOTATION AND MAX/MSP PATCHES

CONCLUSIONS

BIBLIOGRAPHY

GUIDING QUESTIONS

Now we will narrow our scope to exclusively focus on my work *Currents,* which began as a series of research questions for my Wayne State University Master's Thesis in September 2019. My initial driving question was simple: How can a composer use weather data to create music? Several questions spiraled off from there, and in researching these questions I gradually led myself towards the formation of *Currents:*

- How can a program (Max/MSP) be used to access data (live weather readings)?
- What is sonification, and how can a composer use it to translate data into acousmatic sound and notated music?
- How can a composer use sonification to remap new meanings (musical, artistic, historical) onto sound?
- What can historical weather data tell us about the cost of weather disasters? (Money? Lives? Trauma? The Earth?)
- What patterns do we see over time when we look at historical weather data?
- What is an artist's role in crafting narratives to influence the conversation about climate change?

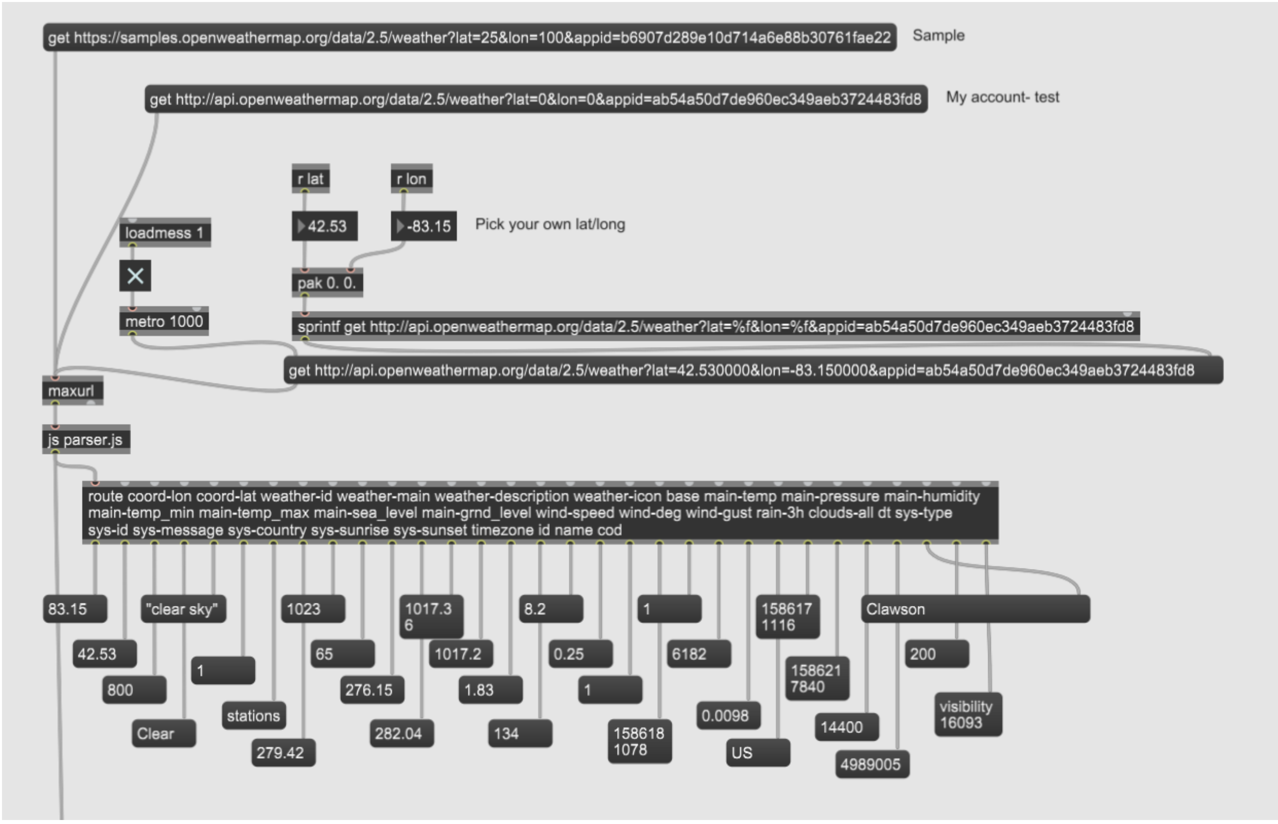
EXPERIMENTS AND TESTS

Live Weather Data (Max/MSP Patch #1)[26]

After perusing the Cycling '74 forums online, I discovered a couple of existing patches that allowed Max/MSP to download data from a web API (Application Program Interface). The first method used the "jit.uldl" object and was a bit more difficult to work with due to the way it parsed data. I opted to work with the method that used the "maxurl" object (which performs http requests to acquire data) and the "js.parser" object (which uses JavaScript to parse the data). The existing patch I found happened to have an example that used an API from the website "Open Weather Map" to gather live weather data.[27] By inputting a longitude and latitude, you could acquire live data about that location (temperature, pressure, humidity, windspeed, etc). Example 4 below shows a picture from the patch.

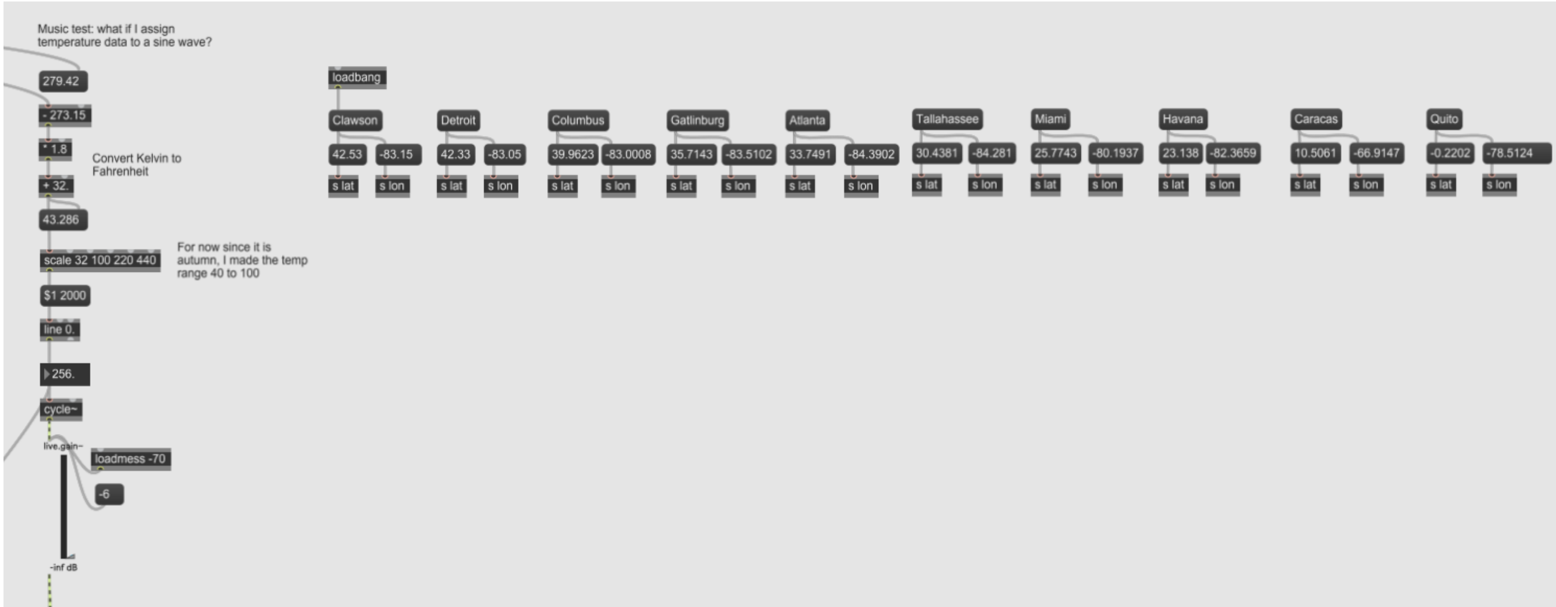
[26] For my own reference: the patch on my computer is titled "0.2 WeatherTest1 (SUCCESSFUL)"
[27] The patch was called "Parsing_Data_From_MaxURL" and was created by Cycling '74 username "Yaniki" (real name: Pawel Janicki). It was posed in a forum entitled "[SHARING] parsing dictionaries from [maxurl]" on 5/5/18.

Example 4



Using this data, I was able to make a very rudimentary sonification of live weather data using Max/MSP. I sonified the temperature data with pitch using a “cycle~” object (a sine wave), with higher temperatures equating to higher pitch. I scaled the temperature to be between 32 and 100 degrees Fahrenheit (I assumed this was an appropriate temperature range given that it was autumn in the Northern hemisphere at the time) and scaled the pitch output to be a one octave range (220-440 Hz, or A3-A4). I chose ten cities to travel through, beginning in my hometown of Clawson, Michigan and gradually traveling south to end up in Quito, Chile (Example 5).

Example 5



Once this test was successful, I gradually added other data elements to transmit more weather data to the listener and to make a more complex soundscape. I added a low sine wave using “cycle~” to sonify pressure (1000-1030 mB = 60-120 Hz, lower pressure = lower pitch), a pulsing staccato note to sonify wind speed (0-40 mph = 500-100 millisecond pulses, which has the inverse relationship of higher wind speed = higher tempo = lower # of milliseconds), and a series of overtones (second to sixth partials) to sonify the percentage of cloud cover (I felt that less cloud cover equated to more overtones to convey the brightness of the sun).

Overall, this initial test was very successful. The stratification of four contrasting sound textures (high sine wave, low sine wave, pulsing note, overtones) not only provided an ample amount of musical interest, but allowed the listener to aurally interpret the weather data in a way that felt satisfying and not too overwhelming. Being able to travel between ten cities worth of weather data gave the piece a sense of direction and travel. However, it was clear that this initial experiment posed a few challenges. I felt that as a composer, it was not substantial enough to stand alone as a purely musical work and functioned more as an "exercise." That is not to say this patch is without its uses; perhaps it could function as a live sound installation in a gallery due to its ambient quality. Moving forward, I was looking to create something with even more sonic variety and an even stronger emotional narrative. Another challenge was the aspect of scaling the data. As an example, it was hard to create the proper temperature range even amongst the ten cities due to their wildly different climates in different seasons. Would the upper limit of 100 degrees be a good upper limit for Havana in the summer? Would the lower limit of 32 degrees be a good lower limit for Michigan in the winter? It was difficult to scale the data to account for potential outliers, and this patch had no corrective measures to address this. Finally, although I was able to acquire weather data from the Open Weather Map API, a cursory test to acquire data from another source failed miserably. I was able to download and access the data, however I was not able to parse it into a workable format (I could only get one data point at a time, and I had no control over which data point I was able to access). This revealed my limitations of understanding how the "js.parser" object in Max works underneath the hood, and it would take several more months of research to crack this code.

Generative System (Patch #2)[28]

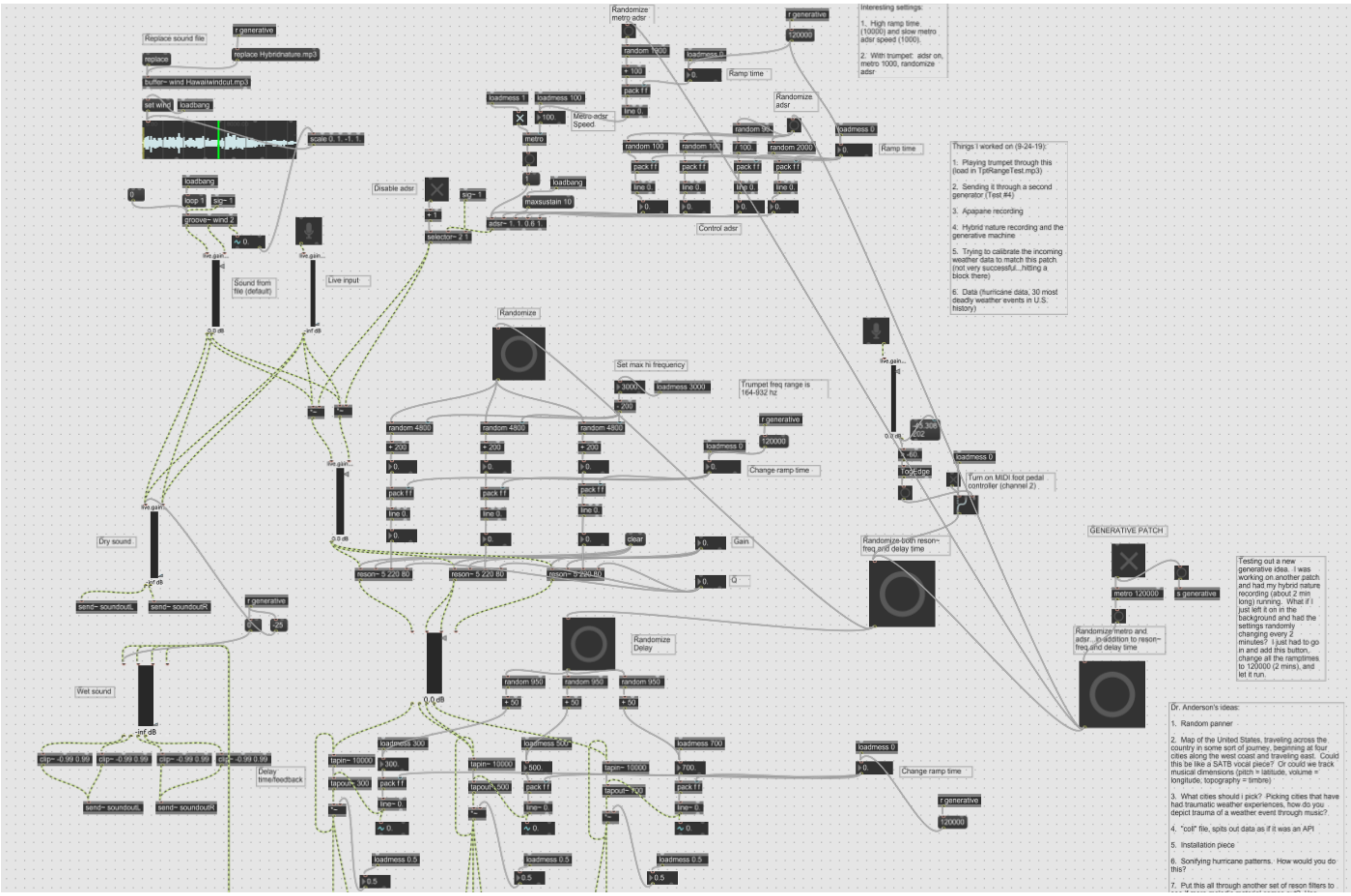
The guiding principle behind my second attempt at a live weather data Max patch was to attain more sonic variety. I wanted to incorporate a greater variety of sound sources beyond

[28] For my own reference: the patch on my computer is titled "0.3 reson filters test (generative Hawaii randomizer too)"

sine waves with the “cycle~” object, as well as a greater variety of effects processing beyond light amounts of reverb. Although I achieved this goal, the patch went in a drastically different direction than expected by becoming a randomized, generative music system that used virtually no data at all.

After experimenting with the “reson~” object (a resonant filter that excites a specific frequency of the incoming sound), I created a system that did a slow sweep (two minutes long) through random frequency bands in the “reson~” object. I initially fed a recording of wind into this system (wind has a quality similar to white noise), but I found the variety of sounds lacking. After trying a few other ideas (playing my live trumpet through this system, duplicating the system and sending it through itself again), I went outside of Max and used a DAW (Digital Audio Workstation) to construct a new sound source. I created a two minute natural soundscape of various field recordings I had taken with my Zoom H4, primarily from my Artist Residency on the Island of Hawai’I in August 2019 (birds, crickets, thunder, coqui frogs). The results were much more musically satisfying when I fed this soundscape into the “reson~” objects, so I began to add other elements of effects processing around this foundational structure. I added an “adsr~” object (attack/decay/sustain/release envelope), and “tapin~ / tapout~” objects (delay lines). Like the “reson~” objects, both of these effects parameters were also randomized to change over time. Once this was all in place, I created one master button to start the entire system. It behaved like a generative music system, repeating the natural soundscape every two minutes while slowly changing the effects processing to create an ever-shifting sonic landscape (Example 6).

Example 6



The use of natural field recordings and effects processing objects ("reson~", "adsr~", "taipin~ / tapout~") greatly improved the variety of sounds at my disposal over the synthesized sounds from Max ("cycle~" objects). The generative nature of this patch was also fascinating as perhaps a future installation/ambient work. However, I struggled with finding an effective way to use weather data to affect this generative system. A major limitation in my first Max patch was also present here: the lack of a musically convincing narrative. This new patch again worked well as an "exercise," but was musically unconvincing in terms of conveying a narrative, structure, or goal-oriented direction.

Synthesis: Live Weather Data and the Generative System (Patch #3)[29]

As my next step, I sought to combine my first two Max/MSP patches. I created three different copies of this generative system from Patch #2. Each of these systems were tied to the live weather data of 10 different U.S. cities, creating a total list of 30 cities used in the patch. Instead of choosing the cities randomly (as I did in my first patch), I found a table on the Weather Underground website detailing the 30 deadliest U.S. weather disasters from 1969-2018. With a bit of additional research, I discovered one significant city to tie to each weather event. My goal was to use these 30 cities to create a narrative, one that not only conveyed the idea of geographical travel but also communicated a map of trauma and human cost throughout history.

The three separate generative systems (again, copies of the system from my second patch) had their parameters controlled by the live weather data in each city: temperature (resonant filter frequency, with the later addition of pitch shifting using the "pfft~ gadget" object), pressure (metronome speed), humidity (release envelope on the adsr), and cloud cover (delay time). When the system was started, it would travel through 10 "events," each lasting for about 12 seconds (so a total duration of 2 minutes). In each "event," three cities would be sonified at the same time. One last detail: included in this patch was a way for the user to manually scale the data using sliders. For instance: the user could determine how

[29] For my own reference: the patch on my computer is titled "0.8 WeatherTest3 (take 2 of inputting city data)."

"wide" they thought the temperature data was going to be (minimum of 0 degrees Fahrenheit, maximum of 100 degrees), as well as how "wide" the actual sonification would be (since temperature was tied to the "reson~" object, you could set your resonant frequency band anywhere between 400 Hz and 7000 Hz).

Unfortunately, the results of this system were not at all successful. The system was overly complex (two Max patches in one) and took a frustrating amount of time to set up (for the 30 cities, I had to look up each latitude/longitude data point and manually type these into Max message boxes myself), all for a soundscape that had so little change as to almost be imperceptible (it just sounded like a wash of noise). Not only was it difficult to perceive the data, but it was also musically unsatisfying. There also seemed to be a mismatch between the sounds being created (relatively pleasant natural sounds with gentle effects processing) and the narrative attempting to be told (deadly weather events). These points illustrate the dangers of overusing data in the process of sonification, suggesting that the use of a few datapoints and a relatively small set of parameters is often a more effective sonification approach. The use of specific cities to convey a weather narrative, as well as the addition of the "scaling sliders," were both steps in the right direction, however.

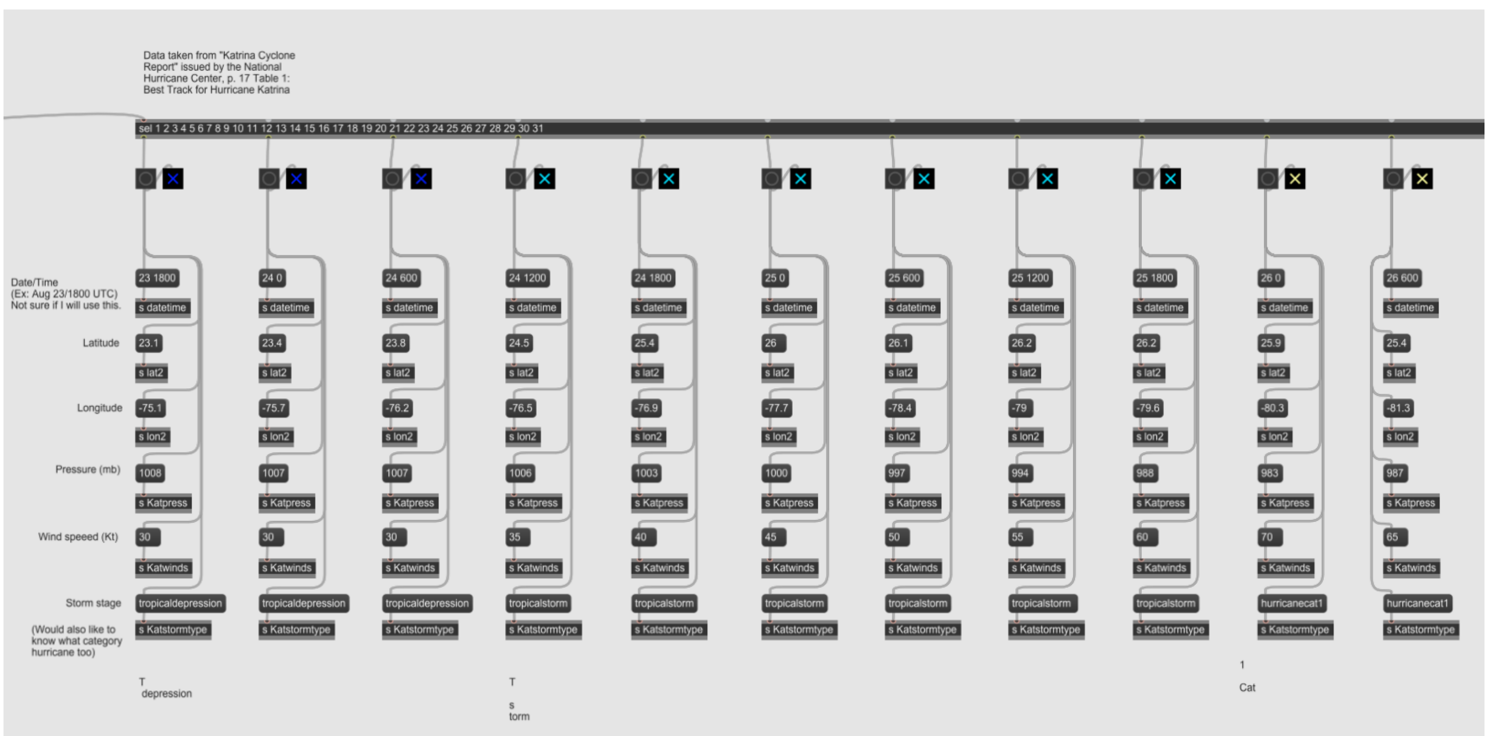
Hurricane Katrina Tracker (Patch #4)[30]

For my next sonification experiment, I decided to focus on one weather event in detail. I had previously studied Hurricane Katrina for my 2017 young concert band work "When the Levees Broke" and thought it would be interesting to compare how the event is depicted

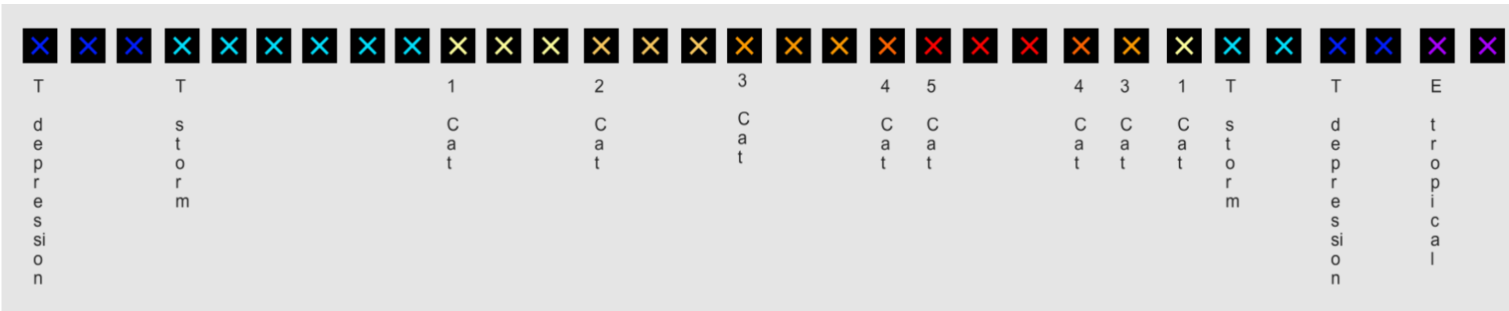
[30] For my own reference: the patch on my computer is titled "0.12 Katrina tracking v.2"

through the lens of sonified data instead of music notation. I used a table in the "Katrina Cyclone Report" issued by the National Hurricane Center to acquire data about Hurricane Katrina's path (date/time, lat/lon, pressure, wind speed, and hurricane category). Since this report came in the form of a pdf, I had no way to enter the data into Max other than by hand. Using "message box," "select," and "counter" objects, I created a system that moved through the data in a timeline fashion from the beginning of the hurricane to the end (Example 7). I also attached "toggle" objects to the timeline that would light up each time a data point was reached, creating a visual path to compliment the sonified path of the hurricane (Example 8).

Example 7

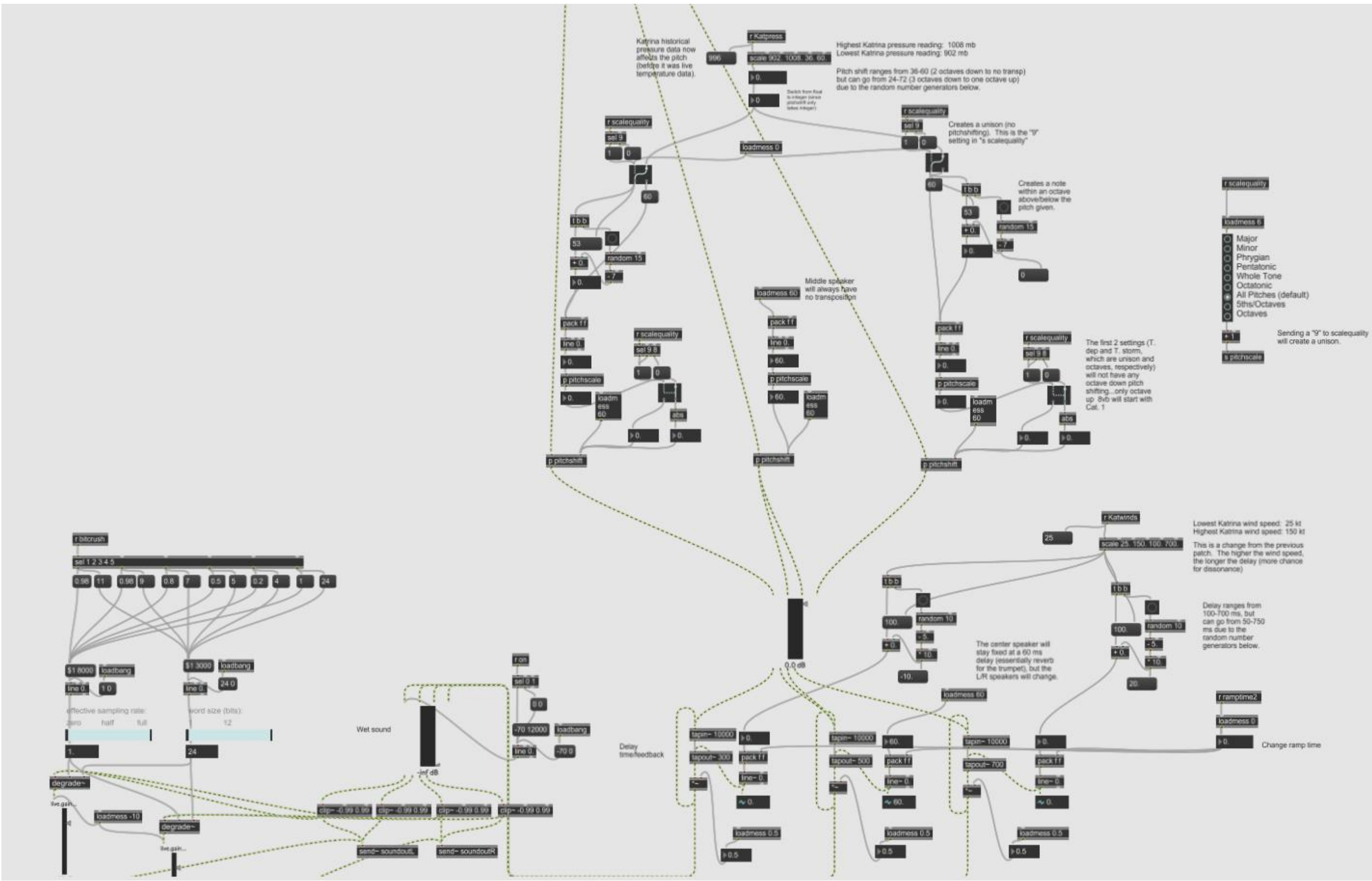


Example 8



This data was fed into three different generative systems. Two of the generative systems used the latitude and longitude data of the hurricane to gather live weather readings (temperature, pressure, humidity, cloud cover) at those locations in real time. The weather readings created effects processing similar to what was done in Patch #3 (reson filters, delay, etc). The sound source was a field recording of wind to give the two systems a gentle, ambient quality. The third generative system used the rest of the hurricane data to add effects processing to a live trumpet player (in the patch, I used a pre-recorded version of myself). The trumpet part borrowed the melody to “When the Levee Breaks,” a 1929 blues song depicting a 1927 breech in the levees similar to what occurred in New Orleans during Hurricane Katrina. Lower pressure data (which indicates a stronger storm) caused the trumpet sound to pitch shift down to lower and more dissonant intervals, faster wind speed data caused slower delays times (which creates more “bleed” and dissonance in the trumpet sound), and stronger hurricane category readings worked with the “degrade~” object to de-sample and distort the trumpet sound (Example 9). The overall effect of the three generative systems was to create a narrative that overlaid the past (the trumpet playing a 1929 blues tune with data from the 2005 hurricane contorting the sound) with the present (the wind sounds depicting the live, and considerably gentler, weather along the hurricane's path today).

Example 9



Two more features were added into the patch at a later time. Once the hurricane became particularly destructive (category 4 or 5), a "buffer~" object began recording the trumpet sound and playing it back two to four times slower speed. This low, droning sound continues to the end of the piece, long after the hurricane data itself has finished its last entry. This sound is representative of the trauma the hurricane inflicted onto the people of New

Orleans and the lingering weight wrapped up in that collective memory. In addition, a granular synthesizer was added to the patch to process a vocal sample taken from Spike Lee's documentary about Hurricane Katrina entitled "When the Levees Broke." The vocal sample was tied to the hurricane category, with percussive snippets during the weaker part of the storm (category 1) giving way to more clear (but frantic) recordings of the sample being played in the "eye" of the storm (category 5).

This experiment took several new steps in sonifying weather data that pointed to new territory away from my first few experiments. The focus on an individual weather event allowed new meanings and contexts to be remapped to the weather data, especially the idea of historical narratives overlaying the past and present. The use of a live instrumentalist in conjunction with the acousmatic sounds pointed the way towards a synthesis of traditional music (written notation, live performers) with electronically sonified music. The use of visuals (the "toggle" objects) to show the hurricane's progression also added another interesting layer that helped amplify the meaning of the sonification for the listener. Finally, this was the first experiment where I achieved effects processing that emphasized distortion (de-sampling), dissonance (pitch shifting), and overall grittiness. This provided a much more physical and visceral response to a more extreme weather event, providing me with a wider sonic pallet to work with in the future.

There were still additional challenges that this experiment revealed. I found myself wanting to sonify *too much*, to use all of the data at my disposal to add more and more sonic layers to the piece. Although I think the kernel of this patch was successful (the three generative systems working with wind sounds and the live trumpet), the later additions I added were not (the “collective memory buffer” and the vocal sample). It was quite easy to get caught up in this “kitchen sink” method when sonifying data, and the result was a piece that sacrificed a clear communication of the data to the listener for the addition of more sonic layers. The balance between these two concepts (adherence to the data versus a musically interesting sonification) still proved to be elusive at times. The final issue, which has been present in every experiment thus far, was the frustrations with data access. Manually having to punch in the Katrina data written in a pdf file was tedious and time consuming. Of course it could be done in this method, but I still sought to find a more automated way to enable Max/MSP to collect and parse data on my behalf.

As one last aside: this patch would later appear as the foundation of the sonification used during the saxophone solo in Movement 4 of *Currents*.

Break Through (Patch #5)[31]

With a week’s worth of research, I was able to successfully collect live weather data using the Open Weather API (Patch #1). After this point, though, I ran into a barrier. I struggled to understand the mechanism for how Max/MSP collected and parsed this data, which made the system limited to only accessing data from Open Weather. If I was going to be able to access other forms of data, I needed another solution. After months of on and off research, a solution emerged. A YouTube tutorial by Federico Foderaro demonstrated a step-by-step

[31] For my own reference: the patches on my computer are in a folder entitled “0.13 Tutorial, Accessing a Weather Web API from Max using Node js”

method to program Max/MSP to access an API.[32] Below, I will briefly summarize the tutorial to give an understanding of how Max/MSP can achieve this method of data collection.

The "Node.js" process is new to version 8 of Max/MSP and is used to run Javascript code outside of a browser. This can be used to send an http request to access web data (in this case, we will be using it to access a JSON file from an API). To do this, a separate JavaScript file needs to be programmed outside of Max using an open source JavaScript editor (I used Visual Studio Code). In the particular tutorial I emulated, the JavaScript code was taking live weather data from an API (Meta Weather). By replacing some of the variables in the programming language, I was able to get the code to access data from a different source (the JSON file for billion dollar weather disasters, which will be discussed later) (Example 10).

Example 10

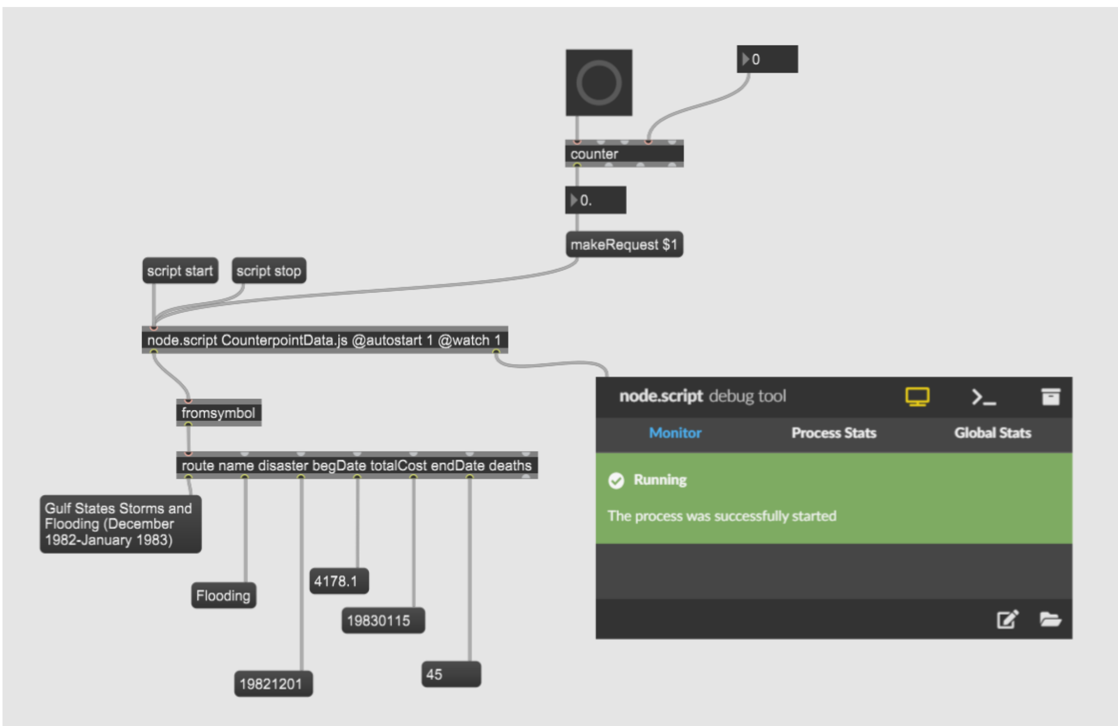
```
const maxApi = require('max-api');

var XMLhttprequest = require("xmlhttprequest").XMLHttpRequest;

let xhttp = new XMLhttprequest ();

let response;

let url = "https://www.ncdc.noaa.gov/billions/events-US-1980-
2019.json";

maxApi.addHandler('makeRequest', (number) => {
    xhttp.open('GET', url, false);
    xhttp.send();
```

[32] The YouTube video is entitled "Access a Weather Web API from Max using Node.js" uploaded by username "Amazing Max Stuff" (real name Federico Foderaro) on 11/24/18. Thanks Dr. Anderson for finding this!

```
    let name;

    name = response.data[number].name;
    maxApi.outlet('name '+name);

    let disaster;

    disaster = response.data[number].disaster;
    maxApi.outlet('disaster '+disaster);

    let begDate;

    begDate = response.data[number].begDate;
    maxApi.outlet('begDate '+begDate);

    let totalCost;

    totalCost = response.data[number].totalCost;
    maxApi.outlet('totalCost '+totalCost);

    let endDate;

    endDate = response.data[number].endDate;
    maxApi.outlet('endDate '+endDate);

    let deaths;

    deaths = response.data[number].deaths;
    maxApi.outlet('deaths '+deaths);

});

xhttp.onreadystatechange = function() {
    if (this.readyState == 4 && this.status == 200) {
        response = JSON.parse(this.responseText);
    }
}
```

Once this file is programmed, it is inserted into the “node.script” object and Max/MSP runs the programming script.[33] Specific requests for data can be made with a “makeRequest” message box (I used a “counter” object to travel through the data row by row) and this data is send to the outlet of the “node.script” object. The data needs to be parsed a bit from there using the “fromsymbol,” “regexp,” and “route” objects (Example 11).

Example 11



A final step I added was a way to store this data in a permanent location. Although the “dict” object might have some capabilities in this area, I had difficulty getting the data to enter properly. Instead, I used a “coll” object to store the data, which was then exported as a

[33] For instance, if my JavaScript file is named “nodeTest.js” I would put it into Max as the object “node.script nodeTest.js”

permanent text (.txt) file on the computer's hard drive. A "counter" object was sometimes used in order to enter the data as sequential rows into the "coll" object. From there, the text file could be re-imported back into the "coll" object at any time. This alleviated a few concerns including latency (I found that making http requests using the "node.script" object had a lag time of at least a few seconds), data availability (what if the data I am accessing online is one day removed?), and internet availability (in a live performance setting, what if connectivity issues interrupted the requests?).

Although this system is versatile and can theoretically be used to access a wide array of data, the difficulty of using two programming languages (Max/MSP and JavaScript) is quite a hurdle and requires a great deal of front-loaded work. As someone with only a passing understanding of JavaScript, I found it incredibly complex to re-code the .js file for my own purposes. I believe this further illustrates the barriers for giving electro-acoustic composers the tools to sonify data, as well as the tension between the two models of sonification discussed earlier in Part 1 of this paper. My first four patches demonstrate Parameter Mapping Sonification (PMSon), where the process of data acquisition is highly specific (i.e. only the live weather data acquired from the Open Weather API), while this fifth patch illustrates Model-Based Sonification (MBS), where data can be acquired from more versatile sources but can be challenging in other aspects (i.e. requiring two programming languages). Until a program like Max/MSP develops a method to streamline this process of data acquisition to be more "in house" (i.e. not require a second programming language), I unfortunately believe data sonification using large data sets might be out of range for the average electro-acoustic composer.

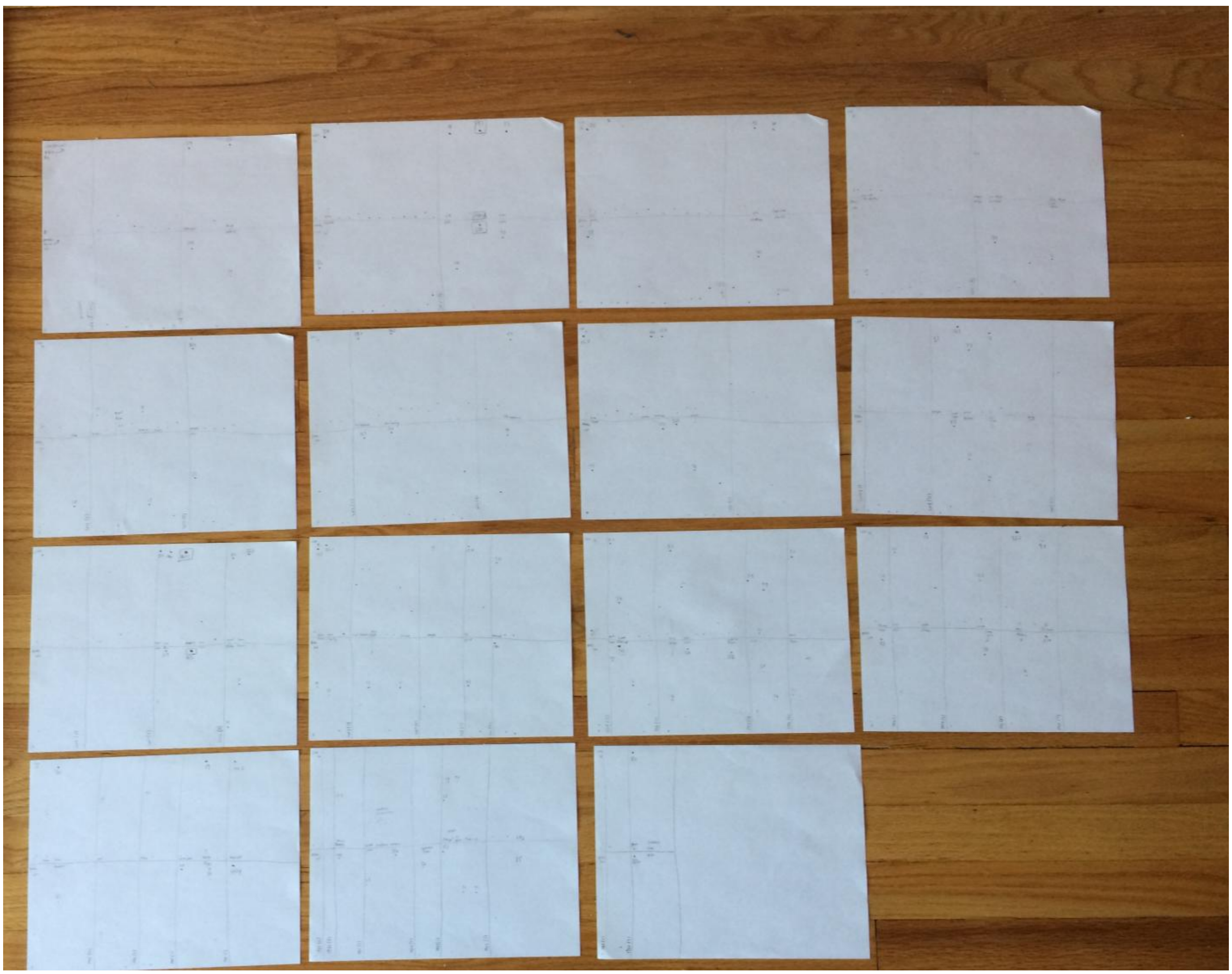
MVT. 1: ACOUSMATIC SONIFICATION

Initial Analysis

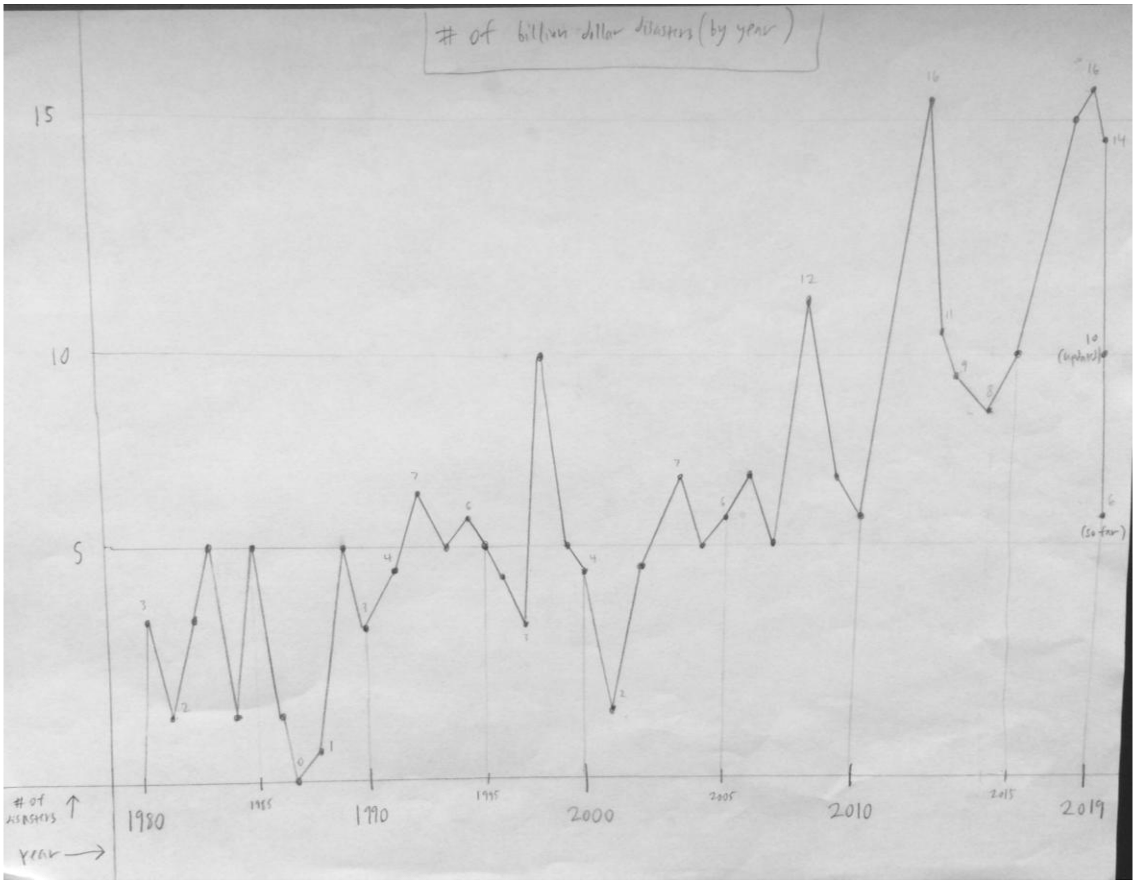
After months of experimentation, I made the choice to narrow my thesis to a single dataset: the NOAA's (National Oceanic and Atmospheric Administration's) database of the last forty years of billion dollar weather events in the United States. I decided on this dataset for a number of reasons. The information was readily available on NOAA's web server in several formats (.pdf, .xml, Excel, and JSON). The dataset was rich with information (each of the 258 data points had the weather event name, type of disaster, beginning/end date, costs, and deaths). Also, I was aiming to sonify the data into a notated work for small ensemble of winds and percussion. There were seven types of weather disasters (tornado, heat wave, freeze, hurricane, winter storm, wildfire, flood), to which I added another category (birds, which is obviously not a weather event and will be explained later). I paired these eight categories to eight instruments (fl, ob, cl, a.sax, tpt, hn, tbn, perc), creating an octet as a nod to some of the great wind octet works (especially Mozart and Stravinsky).

Before I sonified the data with my own musical narrative, I wanted to get a sense of the story the data was trying to tell. I spent a good deal of time in a mode of analysis, sitting down with the entire data set and looking for patterns and trends. My focus was on three data points: cost (in billions of dollars, CPI adjusted), deaths, and the number of weather events per year. This information was placed on a timeline from 1980-2019 to see any trends that emerged over time. I created hand written representations of the data in several ways, including a sprawling overview (across thirteen sheets of paper that I could spread across my entire floor, Example 12), a compact overview (summary graphs that showed all forty years on one piece of paper, Example 13), and a detailed overview (a graph that showed one or two of the strongest events from each of the seven weather categories, Example 14).

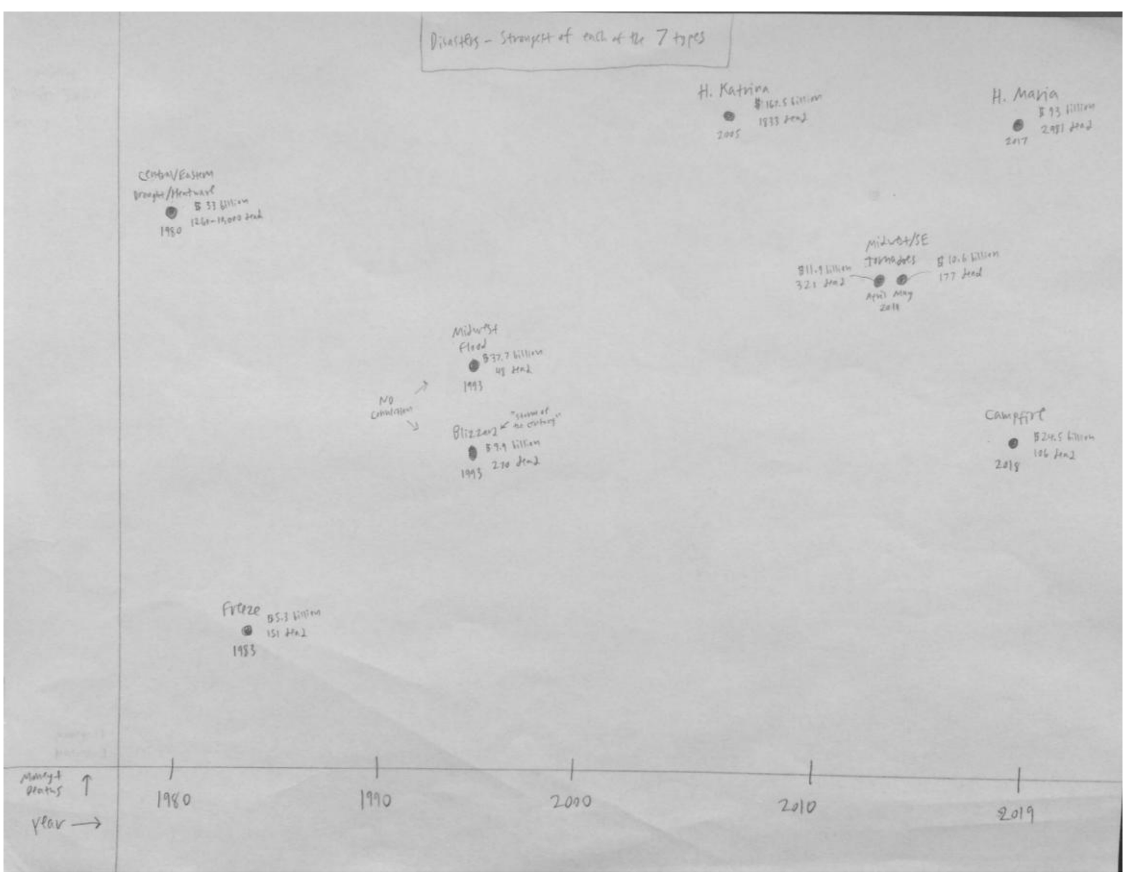
Example 12



Example 13



Example 14



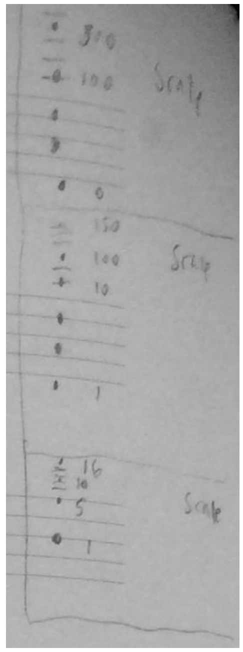
Two trends immediately became apparent. First, the number of billion dollar weather disasters in each year was steadily increasing. There were only two years prior to 2010 that showed eight events or more (1998 and 2008), but between 2010 and 2019 there was not a single year that dipped beneath eight weather events (some went as high as sixteen events per year). Second, the costliest events in each category were spread out quite evenly over the entire timeline (for example, the most costly heat wave fell in 1980 while the most costly wildfire fell in 2018). This illustrated that outlying weather events were sporadic and not connected with the overall rising trend of weather disasters per year. The layout of this graph would later influence my placement of the solo events in the octet.

Music Notation Exercises

I began by doing a series of exercises that sonified the data into written music notation. I assigned my three data points (deaths, cost, and # of events per year) to three different music staves. The top two staves (deaths and cost) were two melodies set to quarter notes and the bottom staff (# of events) was a bassline set to half notes. The bassline acted as a timeline, with each note marking each year from 1980 to 2019 for a total of twenty measures. The data was not plotted as music notes in a rigorous, one-to-one relationship. Rather, I looked at the general shape of the data graphs I created and sonified them into musical phrases using pitch (higher numbers equated to higher pitches and vice versa). I created a small diagram to provide myself a general guideline for how I wanted to scale the data; for instance, the number of deaths between 0 to 100 roughly corresponded to the notes D4-A5 in the top staff (Example

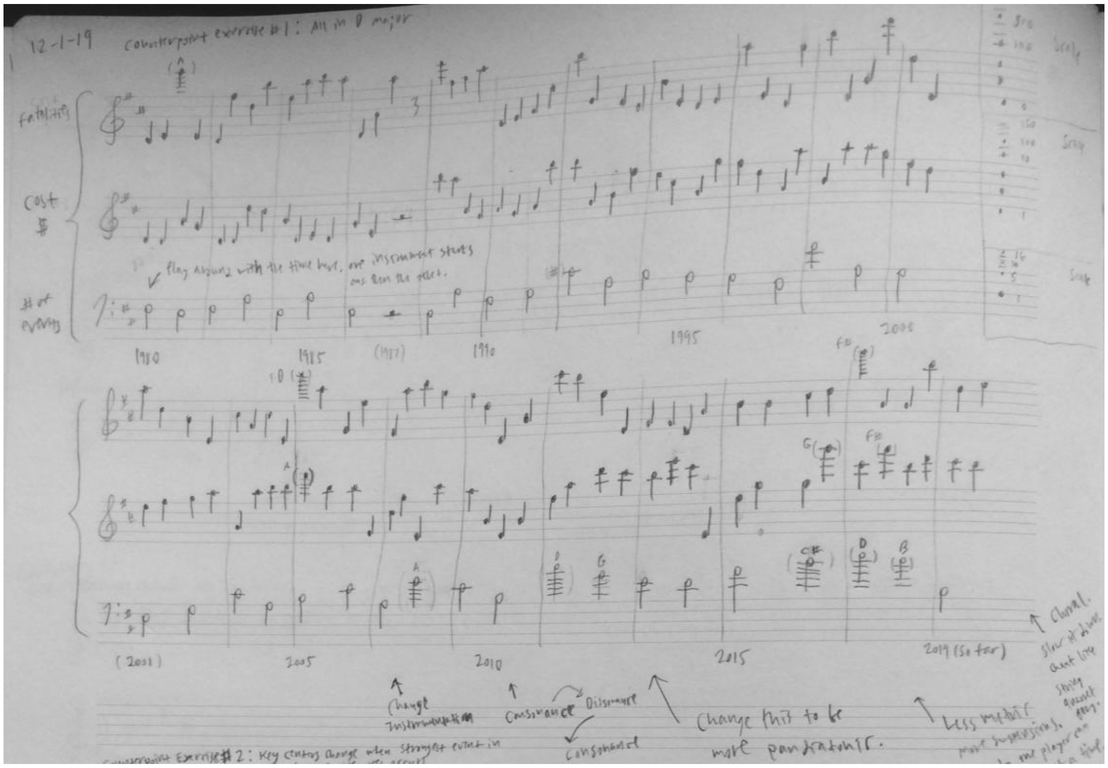
15). All forty years of data were present in the bassline, however I did not include all 258 weather events in my top two staves.

Example 15

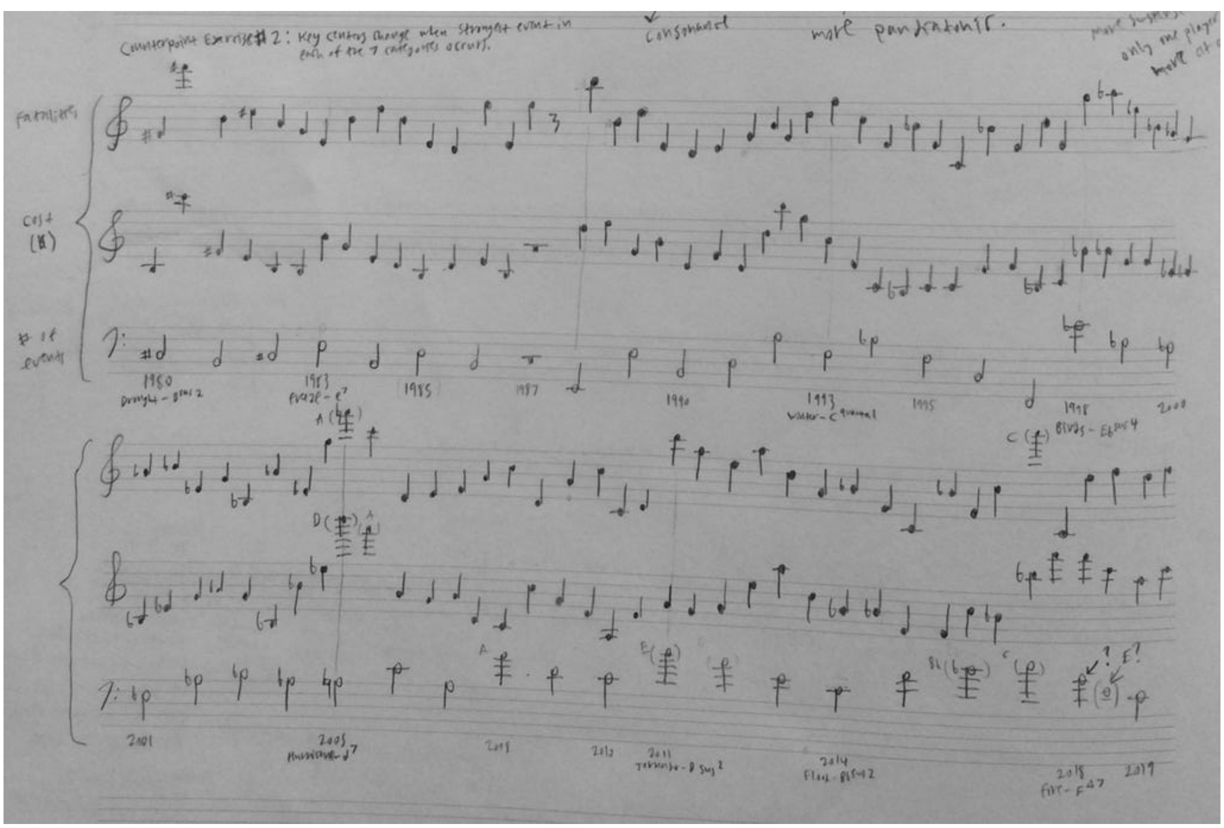


My first exercise was diatonic in the key of D Major (Example 16). My second exercise changed keys when a significant weather event occurred (Example 17). The different key centers corresponded to the harmonies that would later be featured in Movement 6. My third exercise took the second exercise as a model, allowing for looser adherence to the data and more flexible approaches to composing the music itself, especially in regards to rhythm (Example 18). After hand writing these three exercises, I notated them in Dorico using MIDI piano sounds to hear the results. I spent some time revising the first two exercises in Dorico, making subtle shifts in pitch and rhythm to produce a more satisfying musical result. This included a small arrangement of the first exercise as a choral piece for three voices (Example 19).

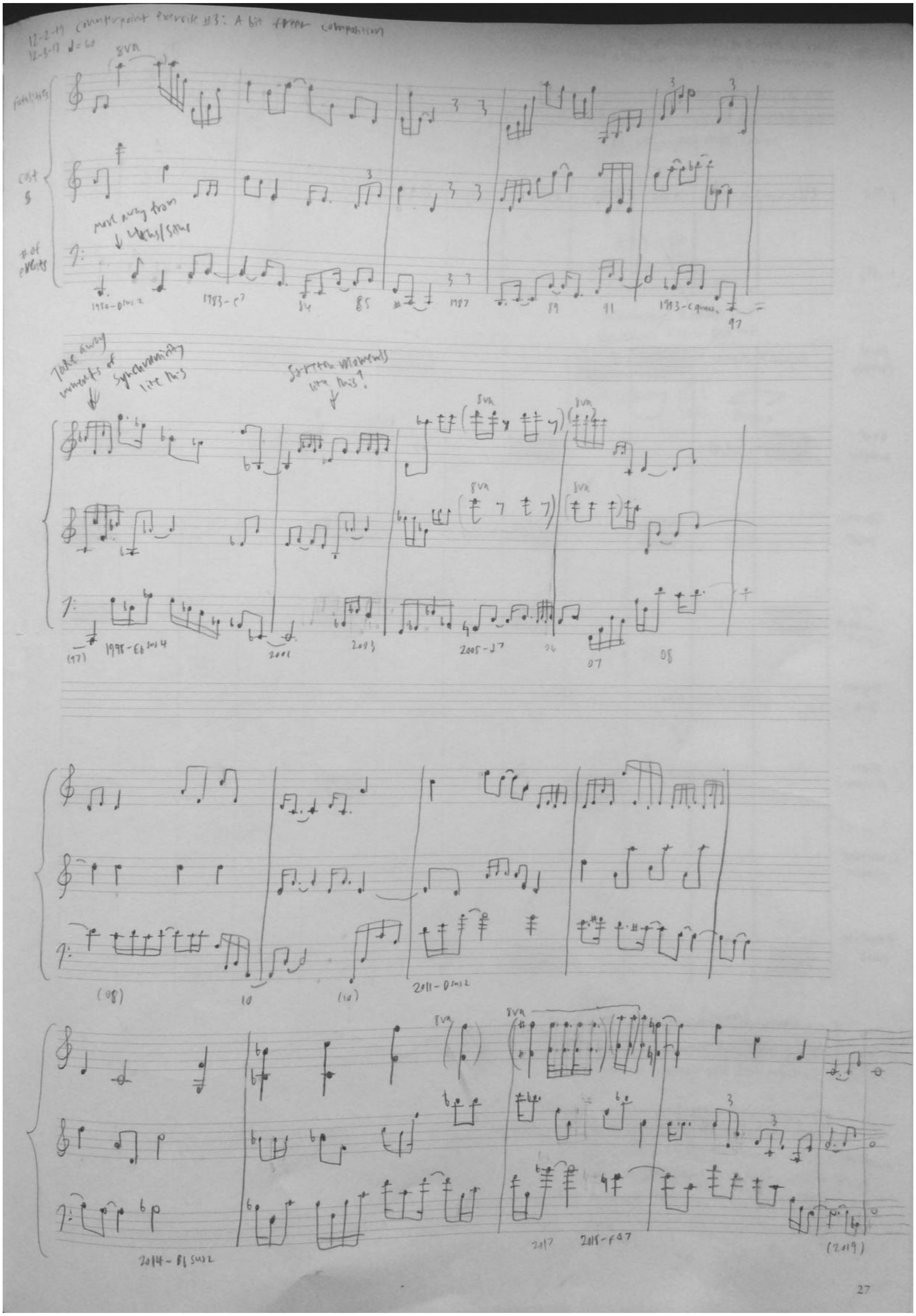
Example 16



Example 17



Example 18


Counterpoint Exercise #3: A bit freer composition
8va
cost
# of events
1987
97
2001
27

Example 19

While these exercises were a good first step towards sonifying the NOAA's dataset, they struggled to convey a narrative both in a musical and statistical sense. Beyond a few interesting moments of counterpoint, the musical phrases felt mechanical and stagnant. The third exercise was by far the most musically interesting due to its rhythmic vitality, but it also suffered from a lack of overall direction and narrative structure. It was hard as a listener to "hear" the data being sonified, which weakened the alarming narrative that I felt the data was trying to convey. I briefly contemplated trying a few more notated exercises with additional parameters of sonification (i.e. having the data affect other musical elements such as dynamics, articulation, formal structure, etc), but I feared that this could only improve the musical aspects. The biggest issue by far was the lost narrative of the data. At this point, I decided to turn back to Max/MSP for a solution to sonify the data in a more convincing way.

Max/MSP: Movement 1 Emerges[34]

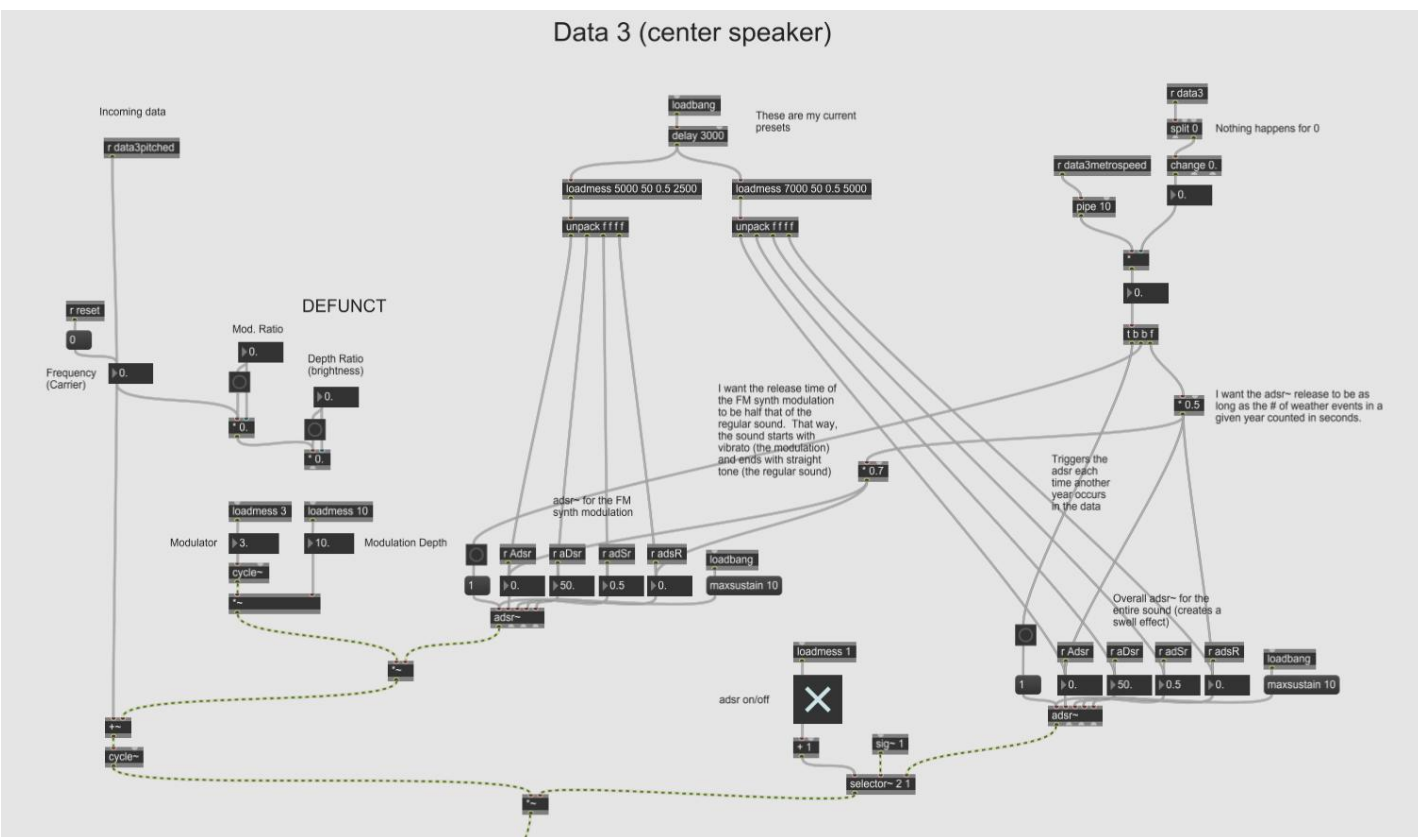
Using the JavaScript parsing system described in the Patch #5 experiment above, I successfully accessed the JSON file from the NOAA's website using Max/MSP. I separated the data into three separate "coll" objects, one each for cost, deaths, and number of events per year. Using a "counter" attached to a "metro" object, I was able to get Max to automatically travel through each data point from 1980-2019. Borrowing an idea from my earlier Katrina tracking patch (Patch #4), I created three graphs that visually represented the data unfurling over time in three colored lines moving across the screen. In terms of rhythm, this initial test was entirely homophonic. All three data points moved in conjunction with each other due to

[34] For my own reference: this section talks about several patches in a folder on my computer entitled "0.15 Counterpoint Exercise." There are 13 different iterations of the patch numbered 15.1 to 15.13, each tracking the small adjustments and additions I added over time.

one master system (the "metro" and "counter" objects) controlling the movement through the data points in the "coll" objects.

Now with the data fully collected, the next step was sonification. I created three basic FM synthesizers (using "cycle~" objects and an "adsr~" envelope) to provide the sound source for each of the three data categories. The various parameters for the FM synthesizer were very fixed (i.e. modulation depth, the attack on the envelope), but in subsequent patches these would become parameters manipulated by the data. The synthesizer's pitch was directly tied to the data numbers; higher data numbers equated to higher pitches and vice versa (Example 20).

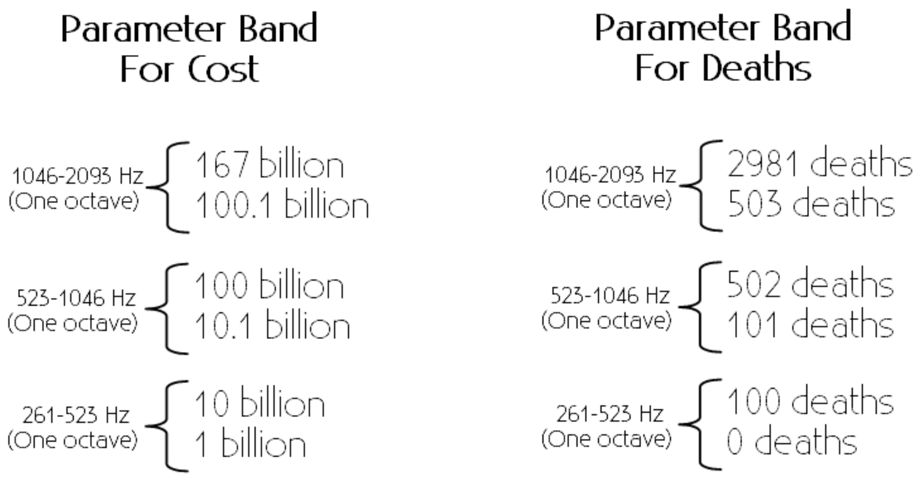
Example 20



To scale the data, I first analyzed the total range of the incoming data points. The cost ranged from 1 to 167 (in billions of dollars), the deaths ranged from 0 to 2981, and the number of events per year ranged from 0 to 16. Next, I determined a total range of five octaves for the synthesizer (65 Hz to 2093 Hz, or C2 to C7). Finally, I put these two elements together for calibration. I fixed the cost and death ranges to a three octave upper range on the synthesizer (261 Hz to 2093 Hz, or C4 to C7) and I fixed the number of events range to a three octave lower range on the synthesizer (65 Hz to 523 Hz, or C2 to C5). I also created an optional system to "snap" the pitch numbers to a scale grid (either a 12 tone system or a major scale system) as an alternative to the Hertz system (which was essentially microtonal). Although this first version of the patch used the Hertz system, most of the subsequent versions opted to snap the pitches to the scale grid for the synthesized sounds (cost/deaths were snapped to a major scale while the number of events was snapped to a 12 tone system).

After an initial test, I quickly realized the calibration needed some fine tuning. The number of events per year was successful due to its relatively limited range of data (0 to 16), but the cost and deaths provided a unique challenge. They mostly stayed in a narrow range of data (cost was 1-100 and deaths were 1-100) with outliers only appearing occasionally. This resulted in a sonification that was very static, with subtle (almost imperceptible) changes in pitch that would suddenly spike when an outlier occurred. To fix this, I created "parameter bands" that would sonify different ranges of data to different ranges of pitches (Example 21).

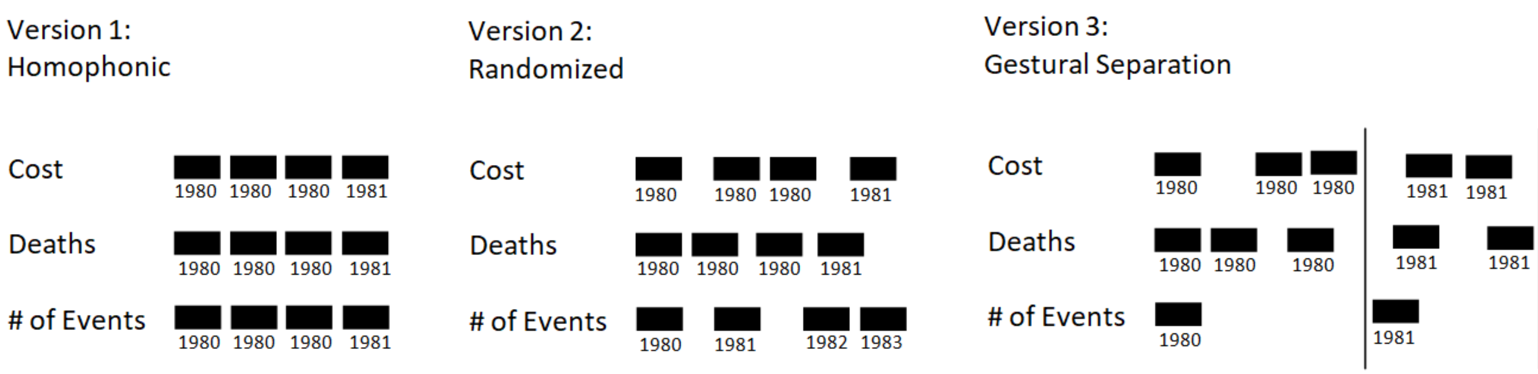
Example 21



After this initial patch was successful, a series of small adjustments and additions gradually led to the final version (Movement 1 of *Currents*). Below, I will detail some of the steps that were made.

Rhythmically, I wanted the three musical lines to be more independent. Using a randomized time system ("drunk" objects attached to the "metro" objects), I created a system that established more rhythmic independence but revealed another issue: the 258 data points for cost and deaths were detaching from the 40 data points for number of events per year. As a result, the piece lacked a coherent sense of "timeline" given the fact that one set of data (the number of events per year) would often finish before the other two sets of data (cost/deaths). I solved this issue by creating a (rather complicated) system that treated each year as a distinct gesture. As an example: When the year 1980 triggered, the cost/deaths of the three weather events that occurred in that year proceeded at their own rhythmic pace; once those three gestures were complete, the data moved on to 1981 (see Example 22, Version 3). This system also had the added benefit of allowing for a slight pause between each year on the timeline, creating more distinct musical phrases with space in between.

Example 22: Progression of rhythmic gestures in different versions of the patch



Another rhythmic element added at a later time was a gradual tempo accelerando over the course of the piece. This was created using a simple “countdown” system that gradually made the “metro” objects travel through the datasets at faster speeds. This not only provided greater musical interest, but also complimented the narrative found in the data. The accelerando serves as a signifier of urgency as the data reveals a steady increase in the number of weather events per year moving towards 2019.

A few minor changes were made to alter the pitch and timbre of the FM synthesizers. Every five years on the timeline, a system was added to transpose the key center of pitches being sent into the FM synthesizer in order to add greater pitch variety. Other parameters in the FM synthesizers (the amount of modulation, the release of the “adsr~” objects) also became tied to shifts in data, which added more detail to the shaping of timbre and articulation.

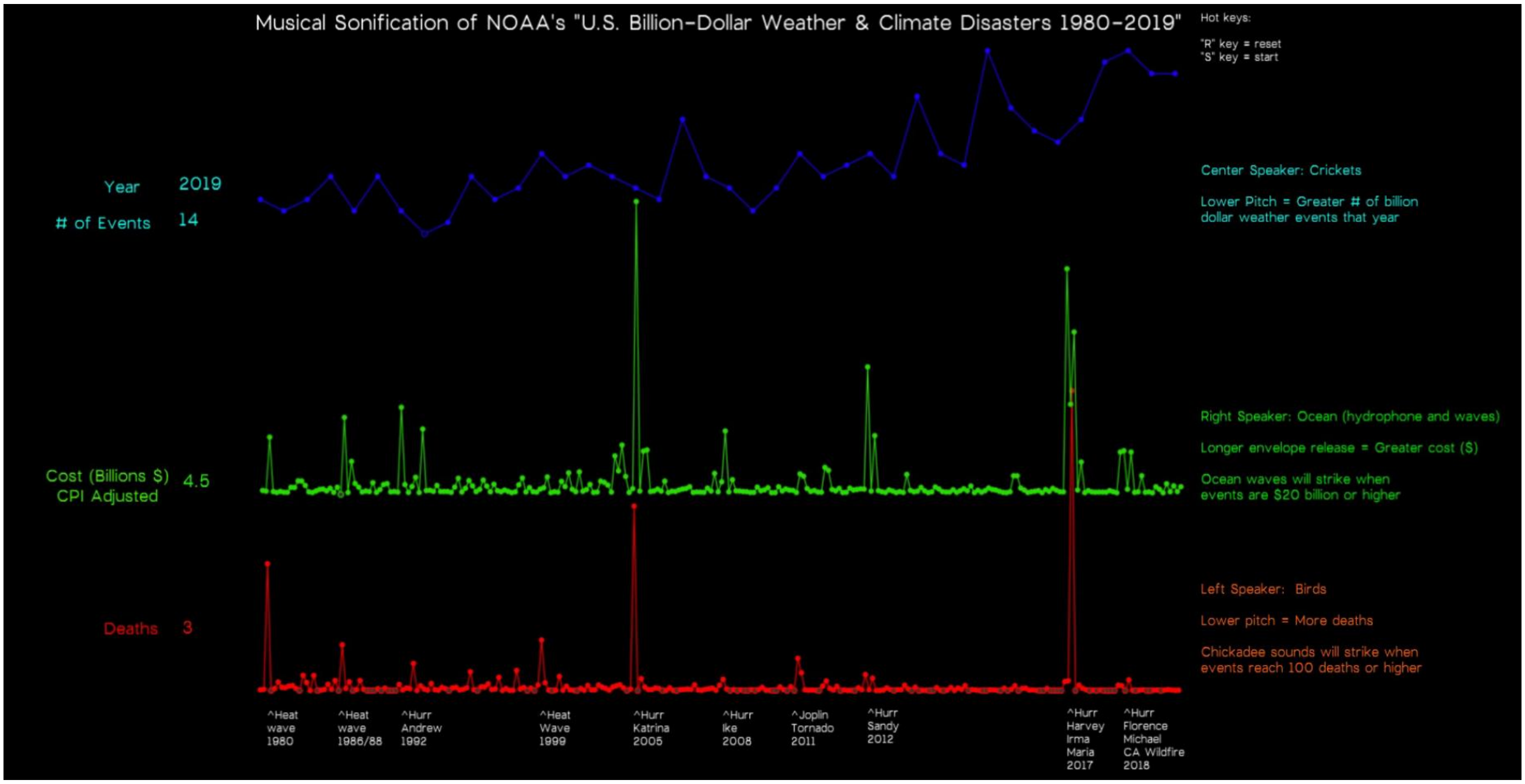
One of the major changes to the piece was the addition of natural sounds, which serves to reinforce the idea of the data representing natural weather forces. The cricket, ocean, and bird sounds were used to sonify the number of events, cost, and deaths (respectively). I chose three natural sounds (crickets, ocean, birds) to represent three different environments (land, sea, and sky) as a way to create an abstract barometer that allows us to check in and take readings on the health of three distant biomes on our planet. These sounds now formed the beginning of the piece, with the stark FM synthesized sounds later fading in as the weather events got stronger and harsher. The field recordings used in this piece were recorded with my Zoom H4 recording device in Great Smoky Mountains National Park and on the Island of Hawai’i. Many effects were used to process the sounds (delay, reverb, panning), but since they were not tied specifically to data (they were randomized) I will not outline them in detail here.

Although the pitch of the FM synthesizers had a direct relationship with the data (higher numbers in the data = higher pitches), I found that pitch shifting the natural sounds higher was not as effective. On the contrary, pitch shifting the sounds of the crickets and the birds *lower* produced eerie results (the crickets resembled alarm bells and the birds sounded ghostly). Therefore, I created an *inverse* relationship with the crickets (higher number of events = lower pitch shifting) and the birds (higher number of deaths = lower pitch shifting). For sonic contrast, I decided to shift the envelope release (i.e. length of articulation) instead of pitch on the underwater hydrophone recording of the ocean (higher cost = longer release). One last addition was made to punctuate notable weather events. Significantly high cost events over $20 billion triggered the sound of ocean waves, while significantly fatal events over 100 deaths triggered the sound of chickadees (in nature, chickadees use an intricate language of bird calls as a way to broadcast perceived threat levels).

One last sound was added late in the process of finalizing this patch. About half way through the piece, another hydrophone recording begins fading in. The sound starts in the right speaker and slowly creeps to fill the left speaker, dropping in pitch as it goes along. When the year 2019 hits, the recording wildly increases in pitch and speed (the result of increasing the "sig~" rate on a "groove~" object). This gesture compliments the rhythmic accelerando discussed earlier, further signifying an urgency as the sound burns and crackles out of control.

Finally, the visual look of the Max/MSP patch was also polished to include a black background, small indicators of major weather events at the bottom of the timeline, and large boxes to show the data numbers (Example 23). They very last addition was the ending, the data being erased and the screen wiping to black as a dramatic finish for the piece.

Example 23



Overall, this was by far my most successful sonification to date. It addressed many of the prior issues of previous attempts, forming a narrative that was both musically satisfying and faithful to the communication of the data. While this patch provided an excellent overview of the entire dataset, I also felt the climate narrative being told was incomplete. The power and trauma behind individual data points, individual *weather events* affecting *people*, was lost in the overview. Now that this acousmatic sonification forming Movement 1 was complete, I decided to turn back towards music notation and acoustic instrumentation in order to analyze subsets of the data in greater detail.

MVT 2-6: NOTATION AND MAX/MSP PATCHES

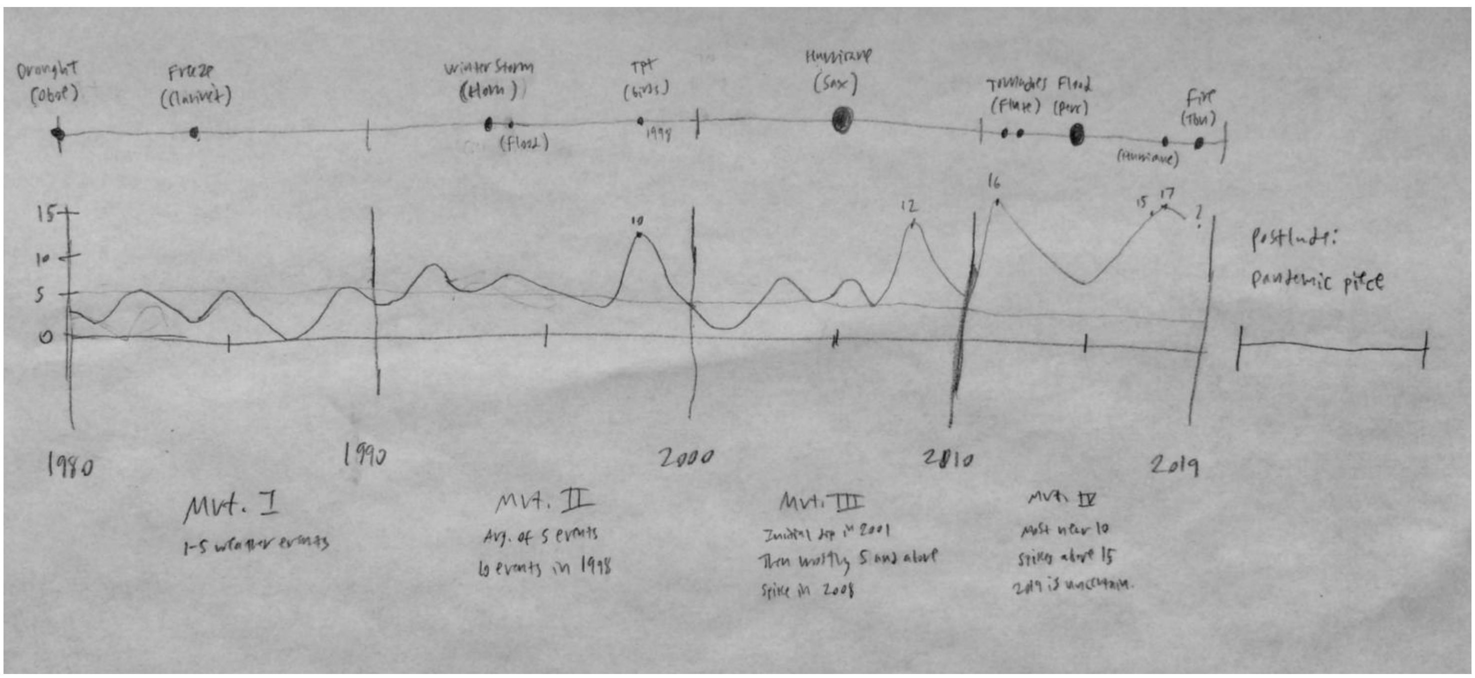
Overview

The rest of this paper focuses on Movements 2 through 6 in *Currents*, which uses a combination of music notation, live wind/percussion players, and live effects processing using Max/MSP to sonify the NOAA's billion dollar weather disasters dataset. A key component of these movements is working with a focused subset of the NOAA's data. Unlike the forty year overview we hear sonified in Movement 1, Movements 2 through 5 each represent one decade in detail: 1980-1989 (Mvt. 2), 1990-1999 (Mvt. 3), 2000-2009 (Mvt. 4), and 2010-2019 (Mvt. 5). In addition, each of the eight instruments are tied to one weather category and given a "solo event" that zooms into one particular weather event:

- Oboe, Drought/Heat Wave, 1980 Heat Wave
- Clarinet, Freeze, 1983 Freeze Event
- Horn, Winter Storm, 1993 "Storm of the Century"
- Trumpet, Birds, 1998 (first year to hit 10 billion dollar disasters)
- Alto Saxophone, Hurricane, 2005 Hurricane Katrina
- Flute, Severe Storm/Tornado, 2011 Joplin Tornado
- Percussion, Flood, 2014 Detroit Flood
- Trombone, Wildfire, 2018 Campfire (Paradise) Wildfire

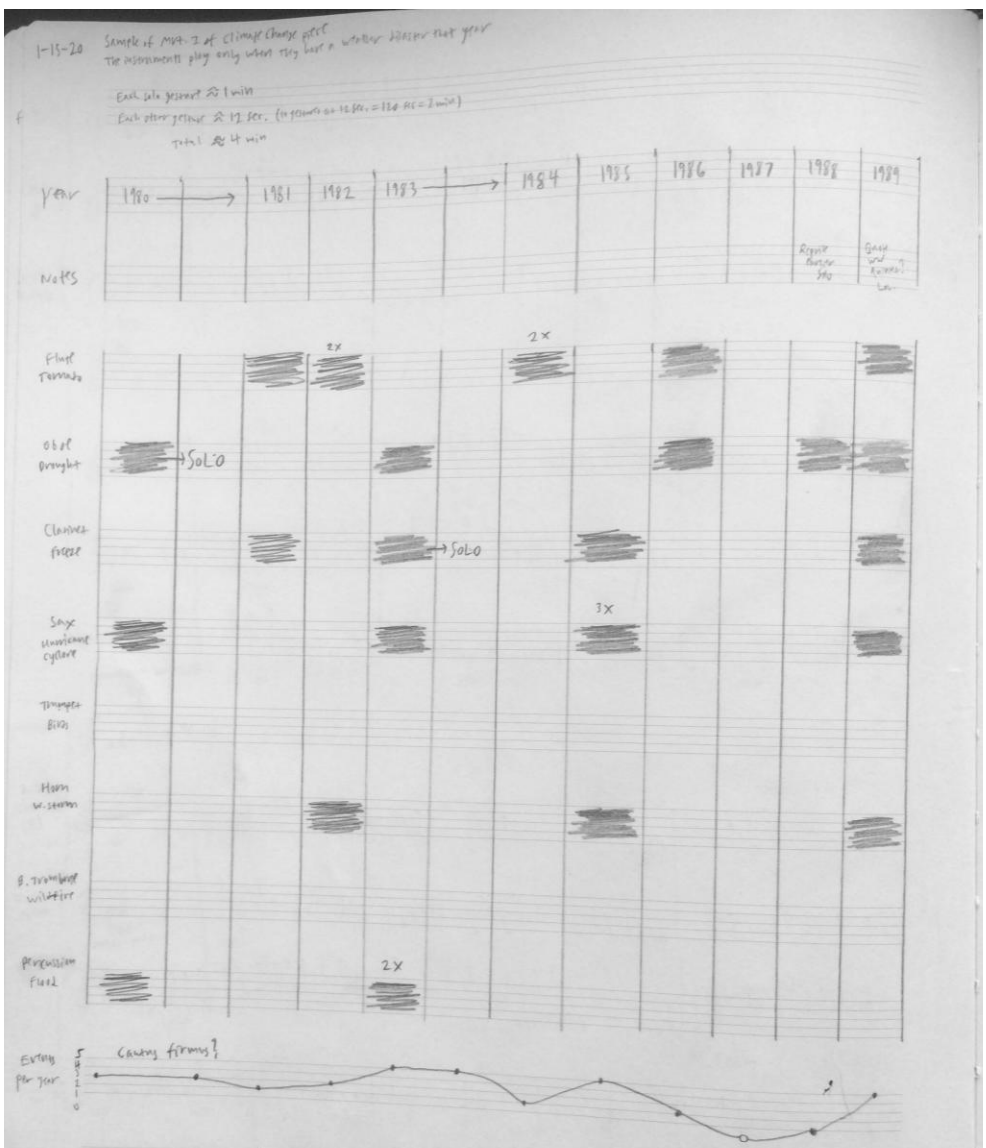
These solo events, which were the first components to be written, provide the lynchpins for the formal structure of the piece. The full octet moments were designed as transitional material to connect these solo moments. The data on the number of weather events per year also guided the large scale structure of the piece, mapping a "line of intensity" that informed the location of climactic moments. All of these elements (movements depicting decades, solo events, the intensity line) can be seen in the preliminary sketch made of the piece in Example 24.

Example 24

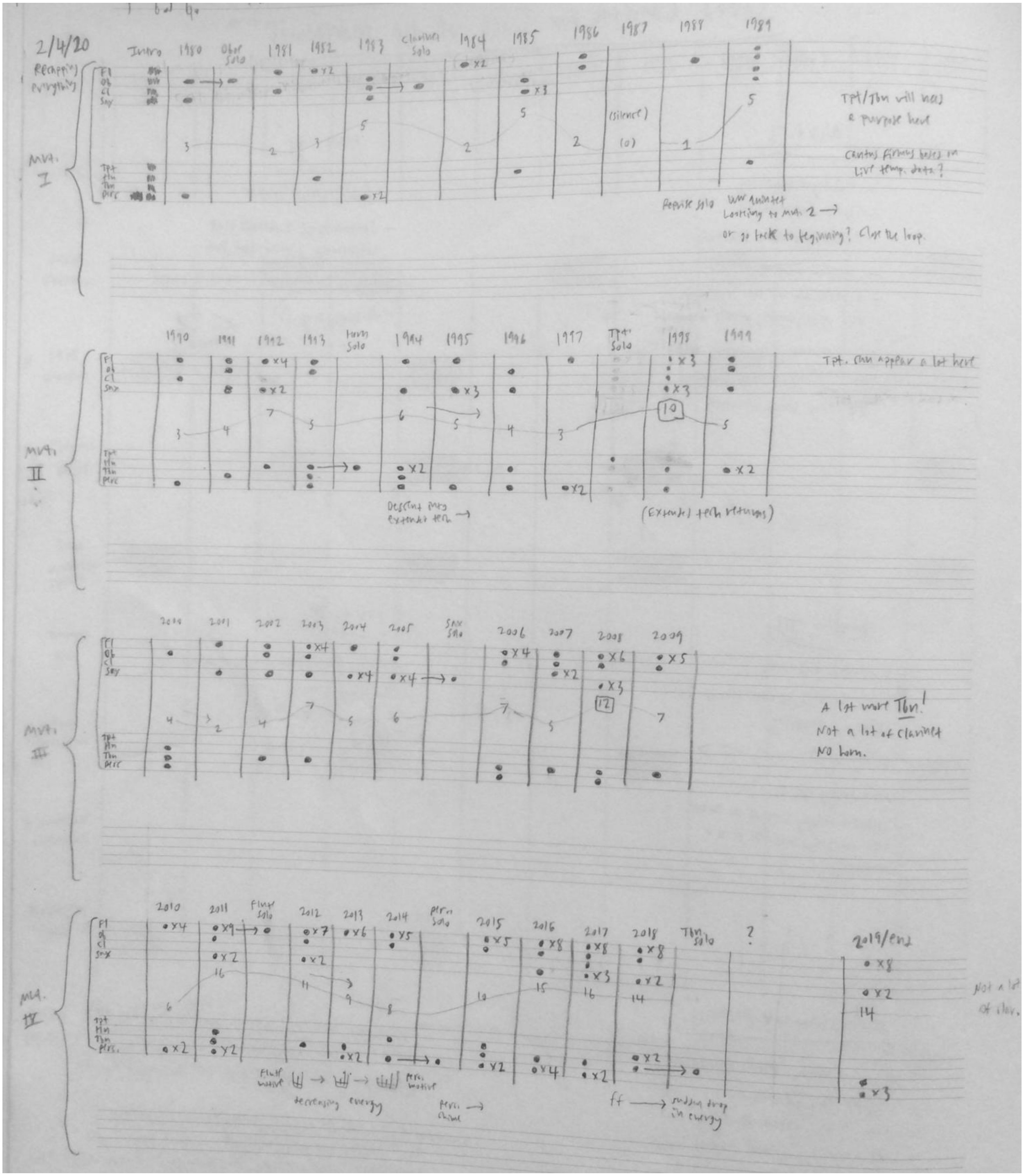


During the full octet moments, each year of data is treated as its own musical gesture. The texture of each gesture is a sonification of the number of weather events; instruments only play if the weather event they are tied to occurred in that year. As an example, there were three billion dollar weather events that occurred in the year 1980: a flood, a hurricane, and a drought. Thus, the "1980 gesture" in Movement 2 only features percussion, saxophone, and oboe (respectively). A representation of Movement 2 can be seen below in Example 25 (shaded in portions means an instrument is playing) and a representation of all the movements can be seen in Example 26 (dots signify an instrument is playing). Small exceptions to the rule were made on a case-by-case basis, often for musical reasons. One example might be the year 2001 in Movement 4, where the melody was given to the "featured" instruments (flute and sax) but other instruments were present in an accompanimental role. Another example might be the year 1998 in Movement 3, which was a climactic moment (first year to break ten billion dollar disasters) and demanded the full octet texture.

Example 25



Example 26

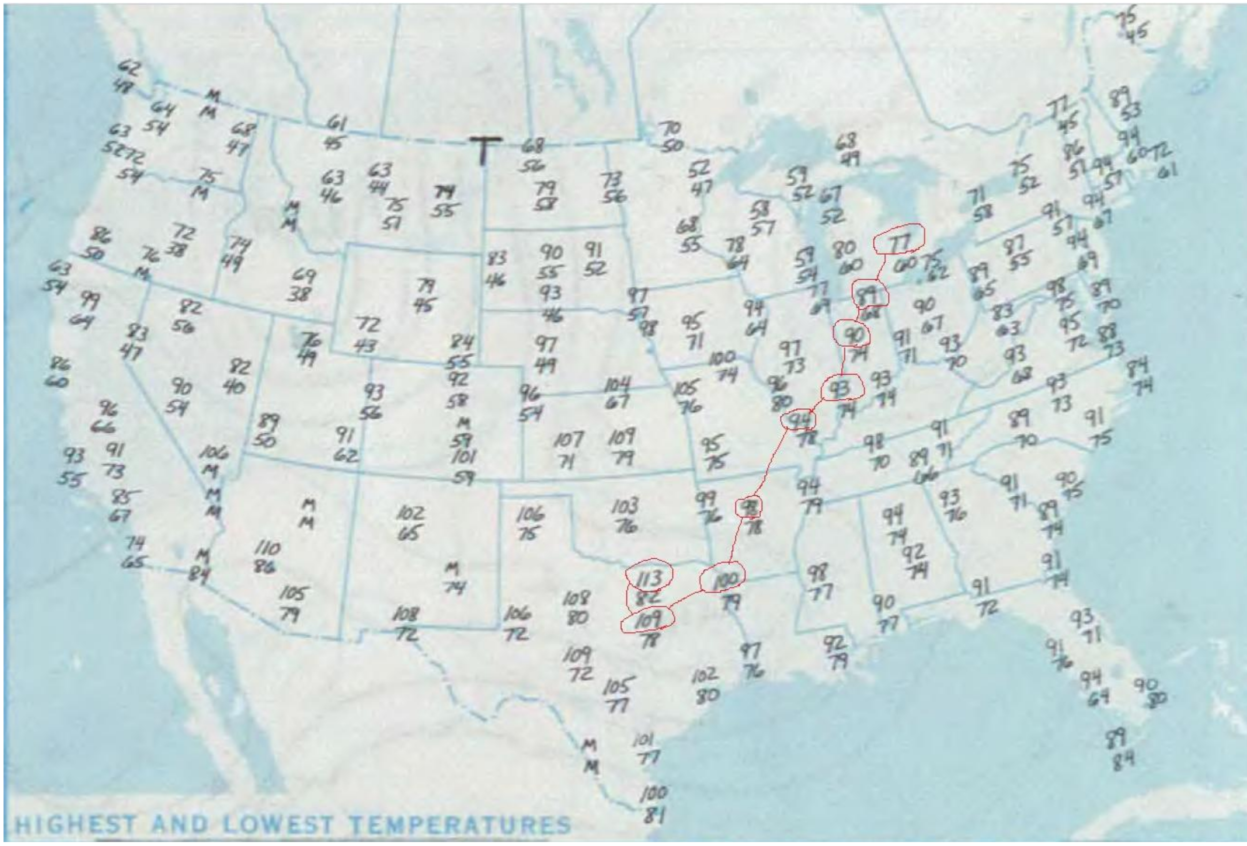


2/4/20
Mvt. I
Intro
1980
Oboe Solo
1981
1982
1983
Clarinet Solo
1984
1985
1986
1987
1988
1989
(silence)
TPT/Tbn will need a purpose here
Mvt. II
1990
1991
1992
1993
Horn Solo
1994
1995
1996
1997
Tpt Solo
1998
1999
(Extended tech returns)
Mvt. III
2000
2001
2002
2003
2004
2005
Sax Solo
2006
2007
2008
2009
A lot more Tbn!
Not a lot of clarinet
No horn.
Mvt. IV
2010
2011
Flute Solo
2012
2013
2014
Perc. Solo
2015
2016
2017
2018
Tbn Solo
2019/end
decreasing energy
ff → sudden drop in energy

Movement 2 (1980-1989)

A thunderous percussion solo jolts the listener away from the electronics/acousmatics of Movement 1 and into the live, acoustic world of Movement 2. The full octet moments are all aleatoric and asynchronous, featuring the ensemble moving gradually through an ascending scale pattern to create a wispy, cloudy texture of sound. The pitches in the scale were initially created from data I was researching for the oboe solo, but I enjoyed the pitch content enough to let it be the defining sound of the entire movement. The pitches were created from reading an NOAA daily temperature map from June 28, 1980, which was one of the hottest days in the 1980 heat wave the oboe solo is depicting. Beginning with my hometown (Detroit) and drawing a line to the epicenter of the heat wave (the 113 degrees in Texas), I created an imaginary thread that rocketed me across geography and time, opening a portal between me and the looming force of this weather event (Example 27). The temperature numbers in this line were sonified by using their corresponding MIDI note values (Example 28) and resulted in a scale whose half step intervals and diminished qualities vaguely recall an octatonic sound world (Example 29). As a general rule when using MIDI note numbers, I did not preserve register and would often shift pitches into different octaves as I saw fit.

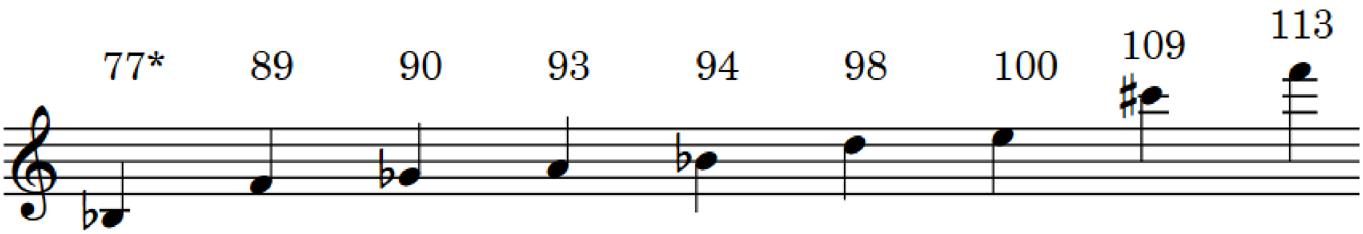
Example 27



Example 28

Note	-1	0	1	2	3	4	5	6	7	8	9
C	0	12	24	36	48	60	72	84	96	108	120
C#	1	13	25	37	49	61	73	85	97	109	121
D	2	14	26	38	50	62	74	86	98	110	122
D#	3	15	27	39	51	63	75	87	99	111	123
E	4	16	28	40	52	64	76	88	100	112	124
F	5	17	29	41	53	65	77	89	101	113	125
F#	6	18	30	42	54	66	78	90	102	114	126
G	7	19	31	43	55	67	79	91	103	115	127
G#	8	20	32	44	56	68	80	92	104	116	
A	9	21	33	45	57	69	81	93	105	117	
A#	10	22	34	46	58	70	82	94	106	118	
B	11	23	35	47	59	71	83	95	107	119	

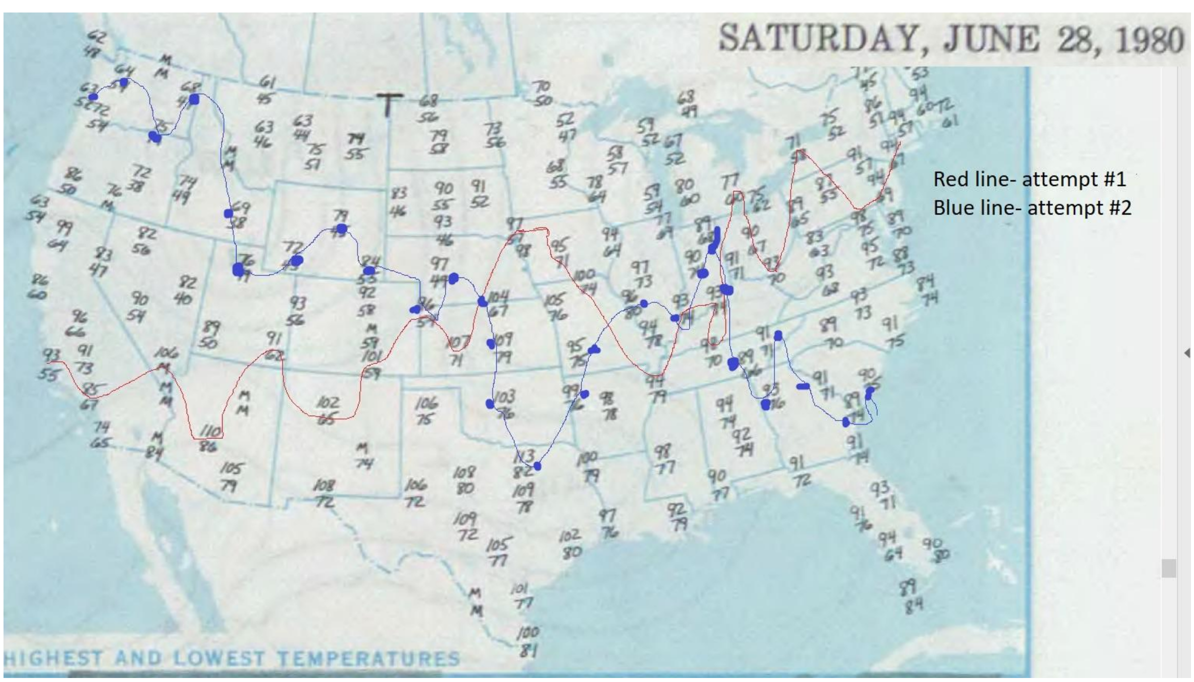
Example 29



*77 is F, but I changed it to Bb
since the next note was already F (89)

After the full octet introduces this scale, the oboe solo quickly beings with its depiction of the 1980 heat wave. The notated pitches were based on the same temperature map used to create the scale discussed above. Starting on the western coast of the United States, I traced two lines that journeyed across the page and sonified the results using MIDI note values (Example 30). The blue line ended up creating a more compelling melodic phrase (Example 31), which was used as an outline for the solo oboe melody (Example 32).

Example 30

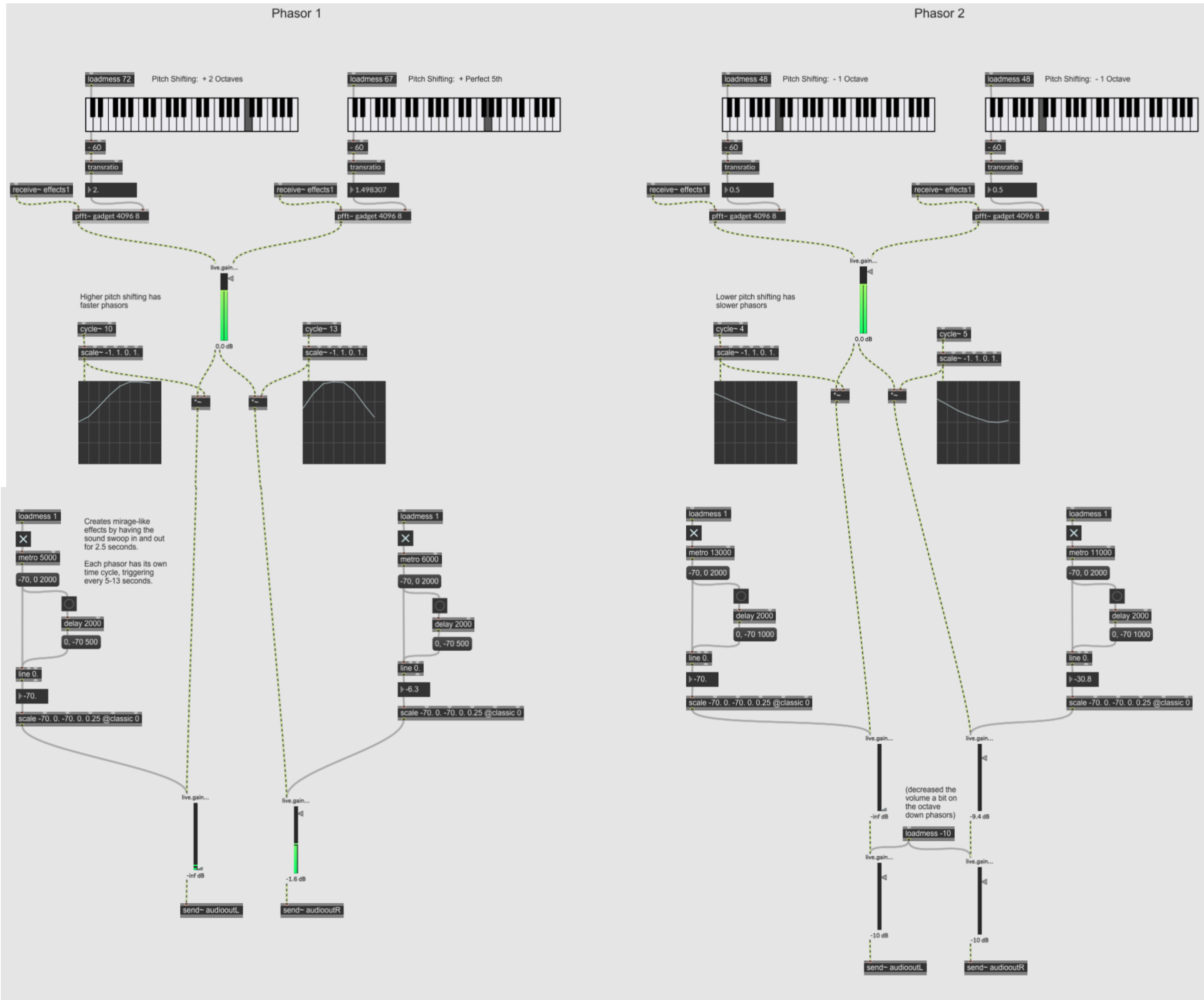


Example 31

Example 32: ms. 5-7 of the oboe event. The first 12 pitches from Example 31 are present here.

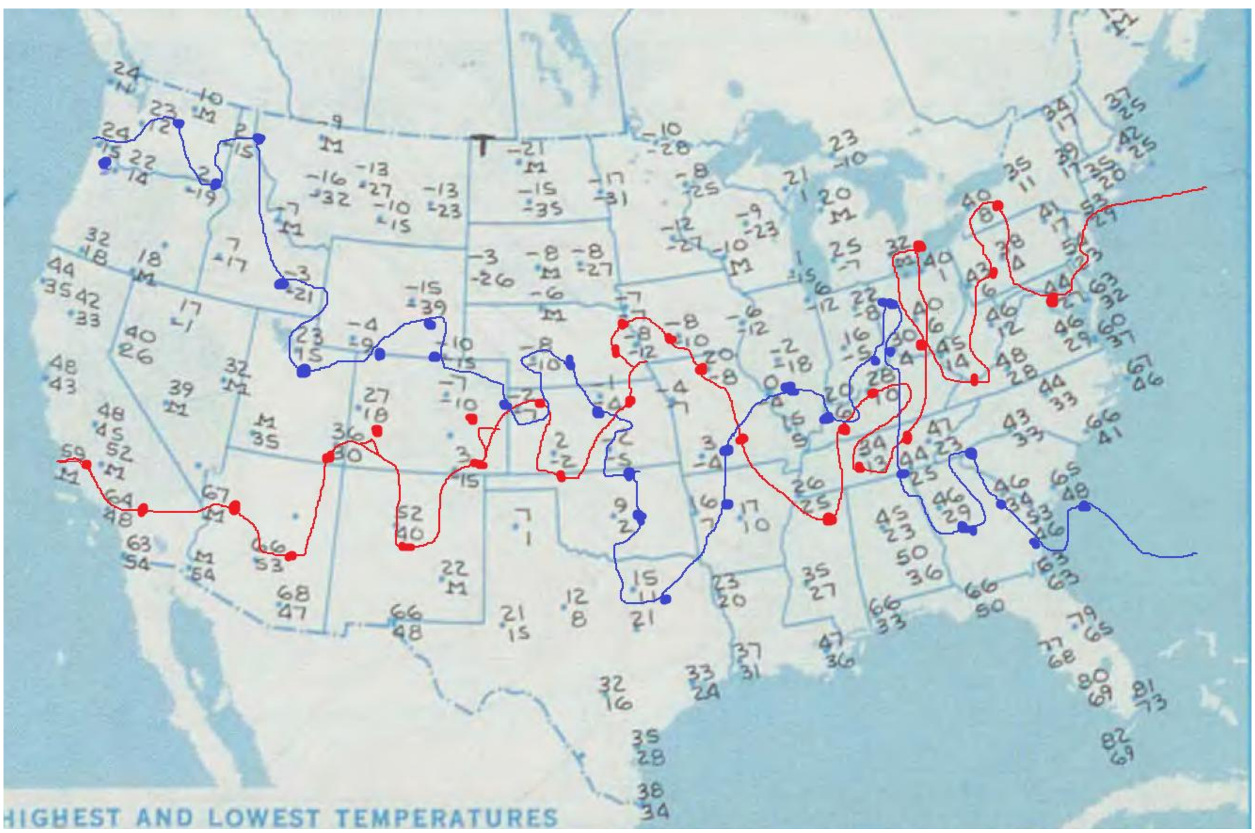
Thinking about droughts and heat waves, I came up with mental imagery relating to deserts, beams of light, and mirages. The first phrase rockets up to a high F, the soaring range of the oboe signifying the scorching heat of a drought. The use of 32nd notes and quick changes in register lends an unstable, flickering quality to the sound. I used Max/MSP to further process the oboe's sound in order to achieve this imagery (Example 33). Two different pitch shifted notes of a perfect 5th and an octave (respectively) gave the oboe a scorching tessitura (left hand column), while pitch shifting down an octave added more depth to the processed sound (right hand column). The pitch shifted sounds were processed with two different phasors (using the "cycle~" object) and then given fleeting dynamic swells (the volume slider swoops up for 2.5 seconds, then rapidly cuts out as the "mirage of sound" disappears).

Example 33



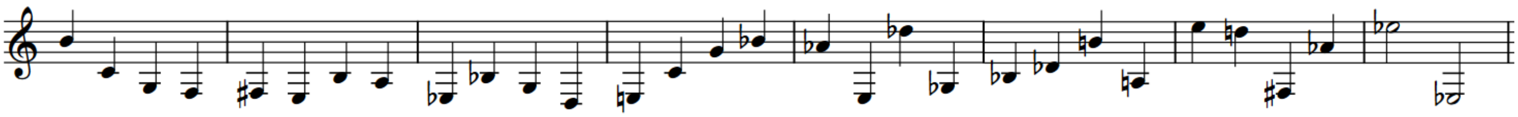
After a brief octet moment, a percussive cymbal scrape introduces the clarinet solo. A temperature map was used to sonify the pitches in a manner similar to the oboe solo, however a different map was pulled to correspond with the date of the clarinet event on December 23, 1983 (Example 34). The red line ended up producing the most compelling pitch content for the clarinet solo (Example 35), and after a slight reworking of the pitches (Example 36) I began composing. Interestingly, the use of the red line provided an effective compliment to the oboe solo; the blue line (oboe solo) and red line (clarinet solo) were drawn inversely from each other on the weather map, establishing the “cold” of the clarinet event as a mirror image to the “heat” of the oboe event.

Example 34



Example 35

Example 36

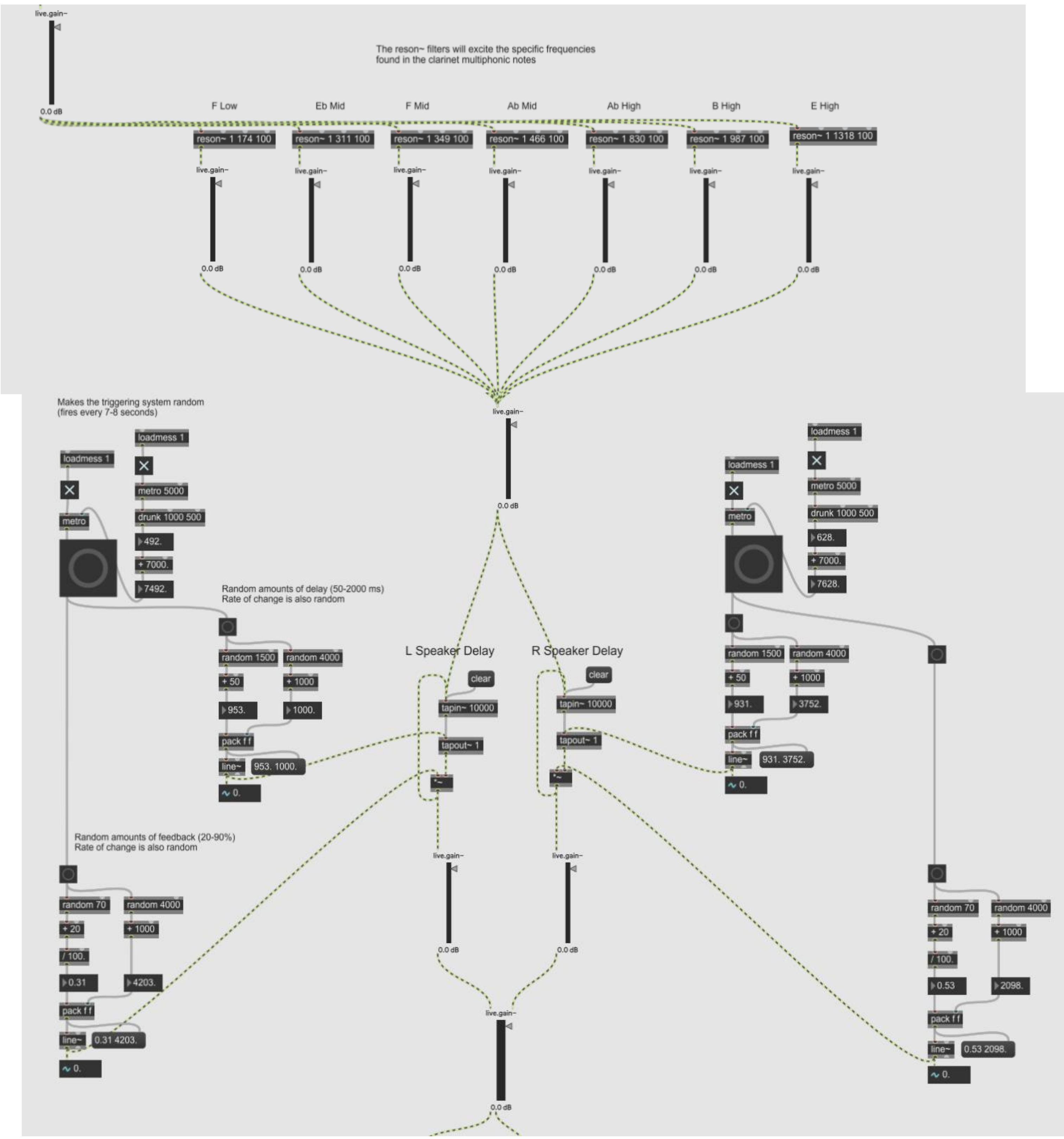


Although the half-speed tempo and low tessitura allude to a "freezing" of sound, the use of multiphonics was the guiding sound concept for this piece. Using Gregory Oakes' extensive online resource of multiphonic recordings of the clarinet, I crafted an outline of "multiphonic moments" that I would be interspersed with the pitch information from the weather map.[35] In listening to the mutiphonics, I imagined icy imagery that was ethereal, crystalline, and refracted. I included cued notes as a way to create a second texture, a window into "another clarinet" playing alongside the first in a refracted, distorted manner. Using resonant filters ("reson~" object), Max/MSP excited specific frequencies in the clarinet's sound (many of which were present in the multiphonics) and fed this information into a randomized

[35] See Gregory Oakes' website: https://www.gregoryoakes.com/multiphonics/index.php

system of delays (delay time and feedback percentage) to further add to the ethereal nature of the clarinet (Example 37).

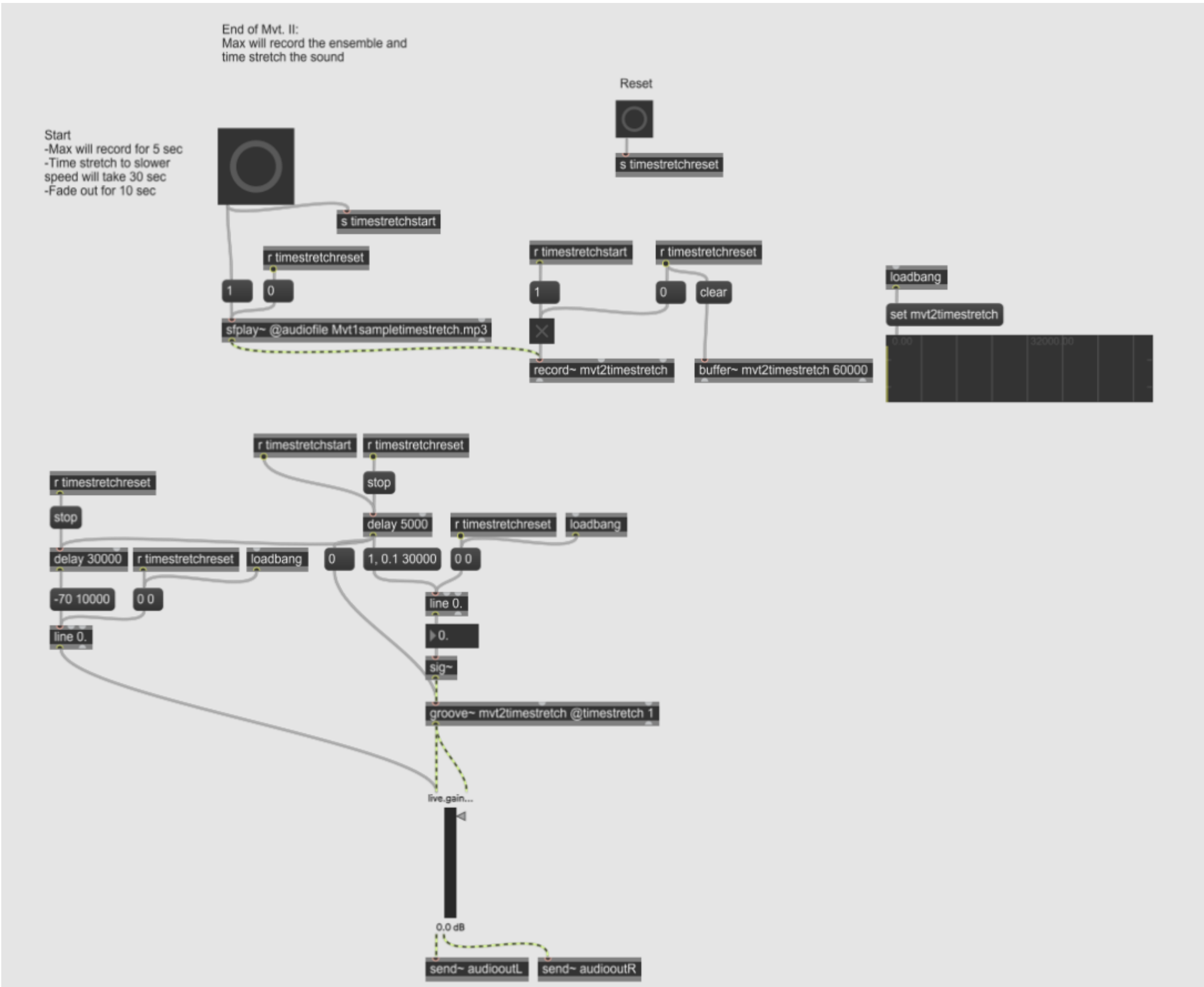
Example 37



The rest of Movement 2 proceeds with the full octet. After a brief silence in 1987 (there were no billion dollar disasters that year), the sole presence of a drought in 1988 reprises the oboe solo from the beginning of the movement. The ascending scale is suddenly transposed for each instrument in 1989, a jarring change signifying the uncertainty of the paths to come. The incorporation of live time-stretching of the ensemble in Max/MSP at the end of the movement (Example 38) came very late in the development of the work and was the result of an accidental occurrence. One of the general difficulties with using digital notation software is realistic playback; since the MIDI sounds created in Dorico failed to capture many of the details in my piece, I decided to create an augmented version that added some of those details back in. I used a time-stretching function in a DAW (Digital Audio Workstation) to create a mock version of the glacial slowing that occurred at the end of Movement 2. The time-stretched sound was far from an accurate replication of live instruments, containing transients and artifacts that distorted the sound in a strange way. However, it perfectly captured the "glacial slowing" sound quality I was pursuing and proved to be compelling enough that it was added in as a Max/MSP part in the notated version of the piece. The fact that a "mock" audio version of *Currents* created with a MIDI recording and a DAW led to a change in the notated music generates many spiraling questions: How can a composer utilize two contrasting creative processes (creating music through notation, creating music through electronic/digital software) to influence their work?[36] What exactly is my work *Currents*? Is it a piece of notation? A series of live sounds produced by acoustic instruments? A MIDI recording electronically processed with a DAW? Are all of these versions valid as distinct entities?

[36] See Jonathan Douglas Anderson, "The Creative Process in Cross-Influential Composition," DMA dissertation, University of North Texas, 2010.

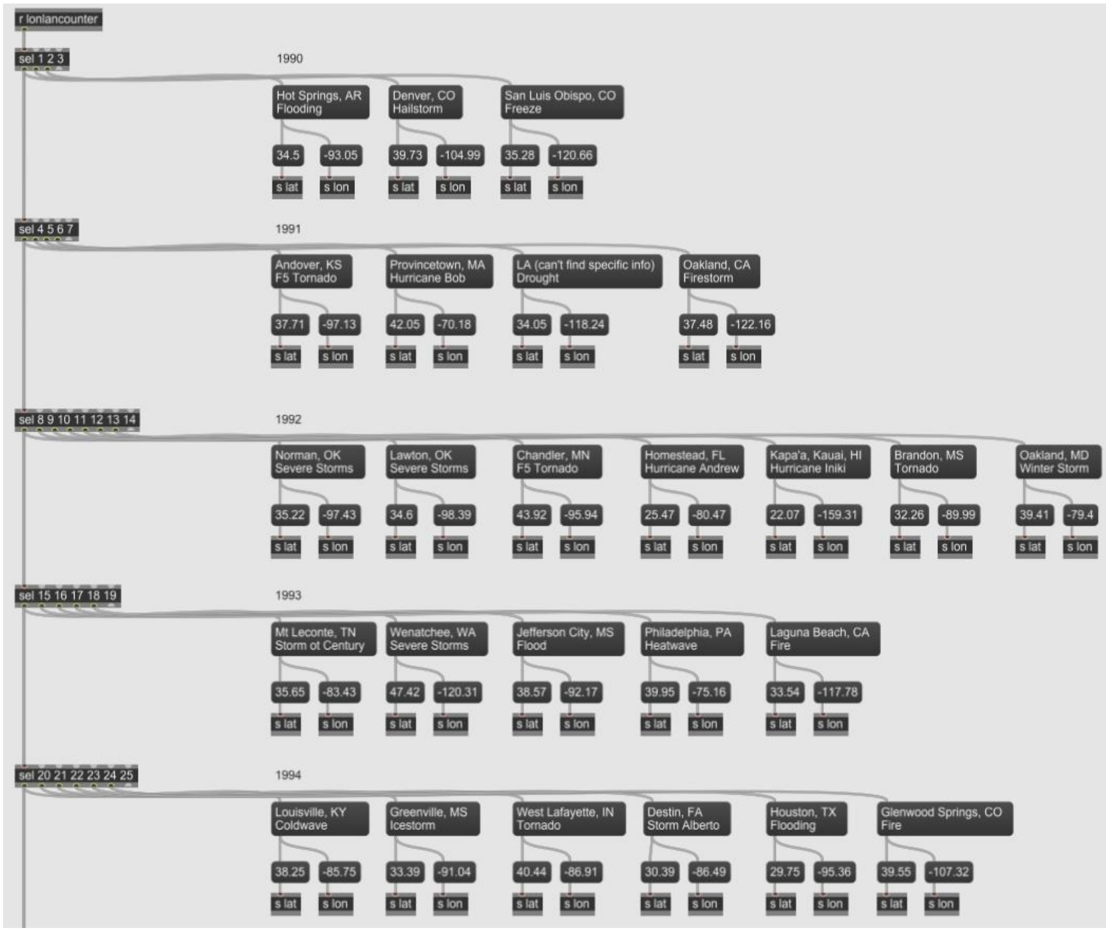
Example 38


End of Mvt. II:
Max will record the ensemble and
time stretch the sound
Reset
s timestretchreset
Start
-Max will record for 5 sec
-Time stretch to slower
speed will take 30 sec
-Fade out for 10 sec
s timestretchstart
r timestretchreset
1
0
sfplay~ @audiofile Mvt1sampletimestretch.mp3
r timestretchstart
r timestretchreset
1
0
clear
record~ mvt2timestretch
buffer~ mvt2timestretch 60000
loadbang
set mvt2timestretch
r timestretchstart
r timestretchreset
stop
r timestretchreset
stop
delay 5000
r timestretchreset
loadbang
delay 30000
r timestretchreset
loadbang
0
1, 0.1 30000
0 0
-70 10000
0 0
line 0.
0.
line 0.
sig~
groove~ mvt2timestretch @timestretch 1
live.gain...
0.0 dB
send~ audiooutL
send~ audiooutR

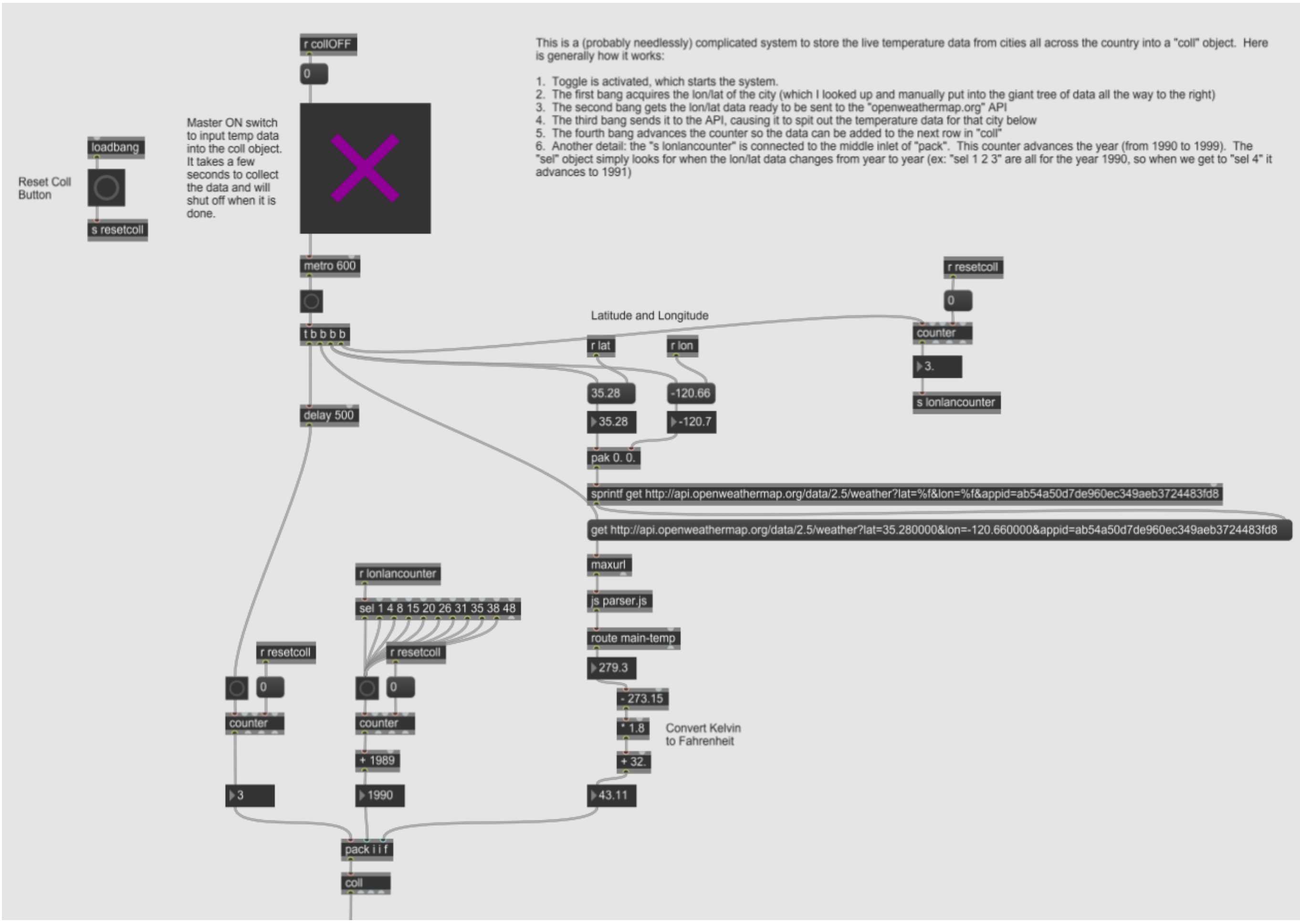
Movement 3 (1990-1999)

It was a lingering goal of mine to revisit my very first experiment with Max/MSP and live weather data and incorporate it somewhere into the fabric of *Currents*. In Movement 3, I utilized this Max patch to create a counterpoint between the live instruments, establishing a dialogue between different compositional processes (electronic composition and notated/instrumental composition) and different layers of meteorological history (past and present). To create the patch, I first completed some additional research on the billion dollar weather events from 1990-1999. For each of the 52 events, I quickly looked up the name of a city that was affected by the event and found the latitude/longitude coordinates of that city. This information was put into a branching "tree" of data using "message box" and "select" objects in Max/MSP (Example 39). Since none of this data (names of cities, lat/lon) was part of the JSON file acquired from the NOAA, it was all individually researched and inputted into Max "by hand." After a few initial tests, it was clear that the lag created from accessing the Open Weather API was going to be an issue. I created a system that inputted the live weather data into a database using a "coll" object, similar to what was done in Movement 1 with the NOAA data (Example 40). The only drawback to this solution is that in a live performance setting, Max needs thirty seconds at the beginning of the movement to collect this data. I opted for this constraint over the issue of lag.

Example 39


r lonlancounter
sel 1 2 3
1990
Hot Springs, AR Flooding
Denver, CO Hailstorm
San Luis Obispo, CO Freeze
34.5
-93.05
39.73
-104.99
35.28
-120.66
s lat
s lon
sel 4 5 6 7
1991
Andover, KS F5 Tornado
Provincetown, MA Hurricane Bob
LA (can't find specific info) Drought
Oakland, CA Firestorm
37.71
-97.13
42.05
-70.18
34.05
-118.24
37.48
-122.16
sel 8 9 10 11 12 13 14
1992
Norman, OK Severe Storms
Lawton, OK Severe Storms
Chandler, MN F5 Tornado
Homestead, FL Hurricane Andrew
Kapa'a, Kauai, HI Hurricane Iniki
Brandon, MS Tornado
Oakland, MD Winter Storm
35.22
-97.43
34.6
-98.39
43.92
-95.94
25.47
-80.47
22.07
-159.31
32.26
-89.99
39.41
-79.4
sel 15 16 17 18 19
1993
Mt Leconte, TN Storm ot Century
Wenatchee, WA Severe Storms
Jefferson City, MS Flood
Philadelphia, PA Heatwave
Laguna Beach, CA Fire
35.65
-83.43
47.42
-120.31
38.57
-92.17
39.95
-75.16
33.54
-117.78
sel 20 21 22 23 24 25
1994
Louisville, KY Coldwave
Greenville, MS Icestorm
West Lafayette, IN Tornado
Destin, FA Storm Alberto
Houston, TX Flooding
Glenwood Springs, CO Fire
38.25
-85.75
33.39
-91.04
40.44
-86.91
30.39
-86.49
29.75
-95.36
39.55
-107.32

Example 40



The live temperature data was converted into pitch and sonified with a FM synthesizer. To scale the data, I chose a range of 0 to 100 degrees Fahrenheit mapped over a four-octave pitch range on a 12 tone grid (65 Hz to 1047 Hz, or C2 to C6). The range of 0 to 100 degrees was designed to cover any temperature extremes the live data might encounter (*Currents* could be performed in any season, after all), and any temperatures that fell outside of this range were simply rounded to 0 or 100, respectively. Parameter bands were also implemented here as well. Individual notes from the FM synthesizer were given slightly different start times to avoid homogenous rhythms. Random amounts of frequency modulation, reverb, phasing, and panning were also applied for timbral diversity. Each gesture lasts approximately seven seconds (or two measures in 70 bpm) and matches the swelling dynamics written in the instrumental parts (crescendo/decrescendo).

As an example of how this patch interacts with the live instruments, I will provide a brief explanation of the first gesture of the movement. The billion dollar weather data for 1990 shows three events occurred that year: a hailstorm, a freeze, and a flood. The Max patch uses latitude and longitude coordinates to gather live temperature data from three cities affected by these events (Denver, CO for the hailstorm, San Luis Obispo, CA for the freeze, and Hot Springs, AR for the flood). The FM synthesizer creates three swelling notes to sonify these three temperatures in measures 1-2. After this gesture is complete, the instruments depicting these events (flute for hailstorm, clarinet for freeze, percussion for flood) play their own gesture in response in measures 3-4. This tension between two different meteorological histories (the live temperatures against the historic weather events from 1990-1999) offers a dualistic, contrapuntal glimpse of the weather's impact on individual cities in the United States.

As the counterpoint continues between the Max patch and the live performers, the instrumental parts develop two musical ideas as they move towards the horn event. The interval of a perfect 4^{th} is a central idea in the movement (and throughout *Currents*), most prominently emerging in the descending patterns in measure 16 leading into the horn solo (where the perfect 4^{th} is also central). There is also a development of rhythmic "toppling," beginning with the wind instruments staggering an eighth note after each percussion entrance (ms. 3, 7) and eventually peeling apart further in time (beginning in ms. 11).

The horn event depicts the 1993 "Storm of the Century," more specifically the astronomical snow falls that resulted from the storm. A table acquired from the NOAA and the National Weather Service indexing the mounting snow fall totals from Raleigh, NC (0.9 inches) up to Mount LeConte, TN (60 inches) was used to sonify the horn melody (Example 41). The right-most digit of each snow fall number (i.e. 0.9 = 9, 13 = 3) was translated into pitch using integer notation, providing a contrast to the MIDI sonification process in Movement 2 (Example 42). The tessitura of the horn melody was loosely governed by the overall height of the snow, increasing as the piece ascended its way from the bottom to the top of the table (see Example 43 for a rough sketch of the horn melody).

Example 41

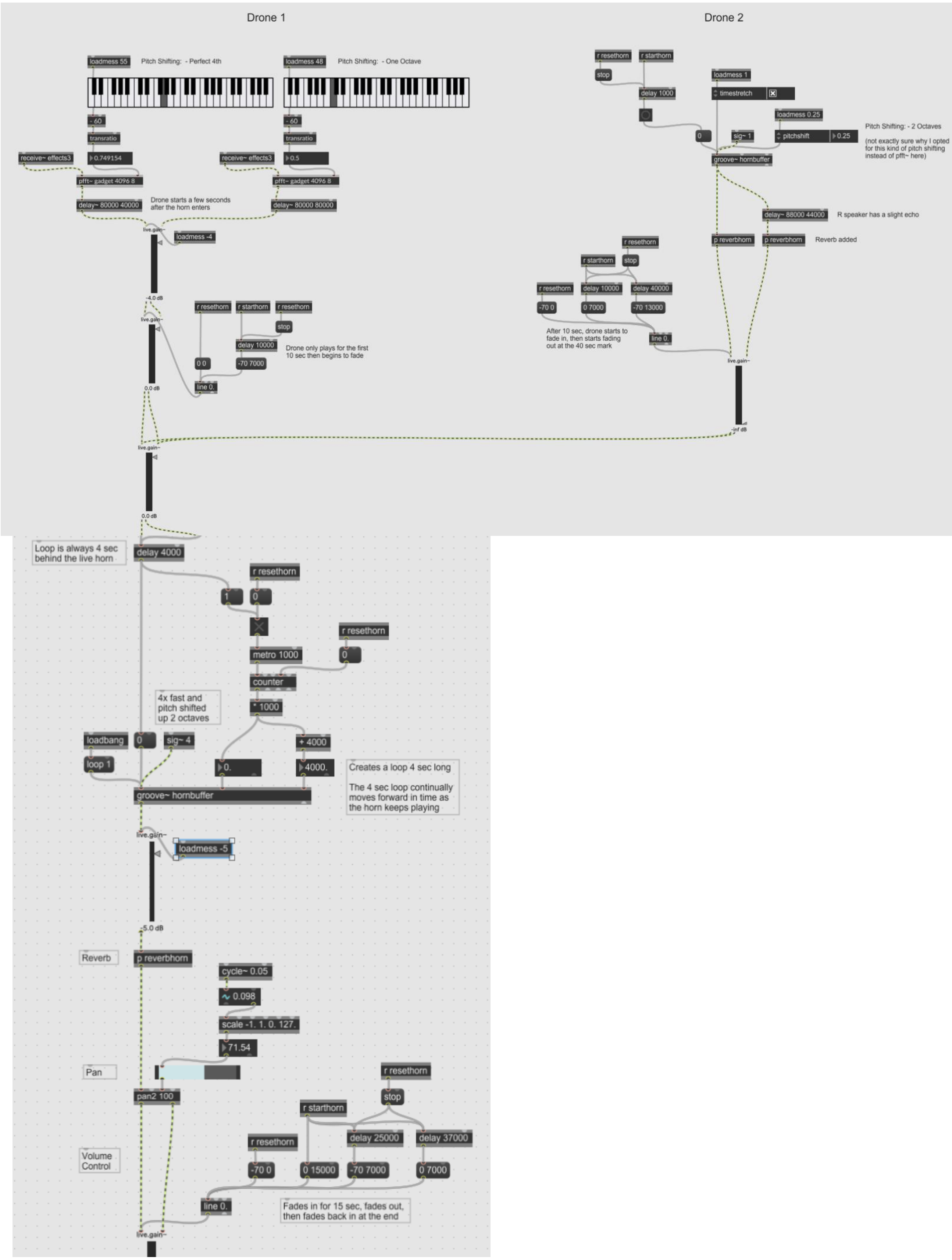
Mount LeConte, TN	60 in.
Mount Mitchell, NC	50 in. Some snow remained on the ground until April 12th
Chattanooga, TN	20 in.
Asheville, NC	18.2 in.
Lake Lure, NC	18 in.
Ellijay, GA	17 in.
Birmingham, AL	17 in.
Lenoir, NC	13 in.
Hickory, NC	10 in.
Greenville-Spartanburg, SC	9.8 in.
Lincolnton, NC	9.2 in.
Greensboro, NC	5.7 in.
Mobile, AL	3 in.
Charlotte, NC	1.6 in.
Siler City, NC	1.5 in.
Columbia, SC	1.2 in.
Raleigh, NC	0.9 in.

Example 42

Example 43

Reflecting on the 60 inch snow fall total on top of the 6,594 foot peak of Mount LeConte, I was inspired by mountain/alpine imagery in Romantic-era works such as Strauss' *An Alpine Symphony*. The interval of a perfect 4th is used throughout to give the horn an open, fanfare-like quality. Max/MSP provides "blankets of snow" in the form of droning echoes pitch shifted down in fourths and octaves from the live horn sound. Together with the timbre of the stopped horn, my programming captures the glittery quality of the snowy landscape by recording four-second loops of the horn transposed and quadrupled in speed (Example 44)

Example 44



Drone 1
Drone 2
loadmess 55
Pitch Shifting: - Perfect 4th
loadmess 48
Pitch Shifting: - One Octave
- 60
transratio
0.749154
0.5
receive~ effects3
pfft~ gadget 4096 8
delay~ 80000 40000
delay~ 80000 80000
Drone starts a few seconds after the horn enters
live.gain~
loadmess -4
-4.0 dB
r resethorn
r starthorn
stop
delay 10000
0 0
-70 7000
line 0.
Drone only plays for the first 10 sec then begins to fade
0.0 dB
delay 1000
loadmess 1
timestretch
loadmess 0.25
sig~ 1
pitchshift
0.25
Pitch Shifting: - 2 Octaves
(not exactly sure why I opted for this kind of pitch shifting instead of pfft~ here)
groove~ hornbuffer
delay~ 88000 44000
R speaker has a slight echo
p reverbhorn
Reverb added
delay 40000
-70 0
0 7000
-70 13000
After 10 sec, drone starts to fade in, then starts fading out at the 40 sec mark
-inf dB
Loop is always 4 sec behind the live horn
delay 4000
1
0
metro 1000
counter
* 1000
+ 4000
4x fast and pitch shifted up 2 octaves
loadbang
loop 1
sig~ 4
0.
4000.
Creates a loop 4 sec long
The 4 sec loop continually moves forward in time as the horn keeps playing
loadmess -5
-5.0 dB
Reverb
cycle~ 0.05
0.098
scale -1. 1. 0. 127.
71.54
Pan
pan2 100
delay 25000
delay 37000
Volume Control
0 15000
Fades in for 15 sec, fades out, then fades back in at the end

After the horn event, the dialogue between the live electronics and the full octet continues. The interval of a 4^{th} exerts its continued dominance, however references to the scale in Movement 2 (ms. 26, 30) begin to undermine it. In the second half of their gestures, the instruments begin breaking off into ornaments and extended techniques (air, keys, slap tongue, half valving, stopped/muted gestures, glissandos, rims, trills) moving the piece towards the upcoming trumpet event. The flute and percussion in measure 34 especially capture the high pitched chattering of bird sounds as the trumpet takes the lead.

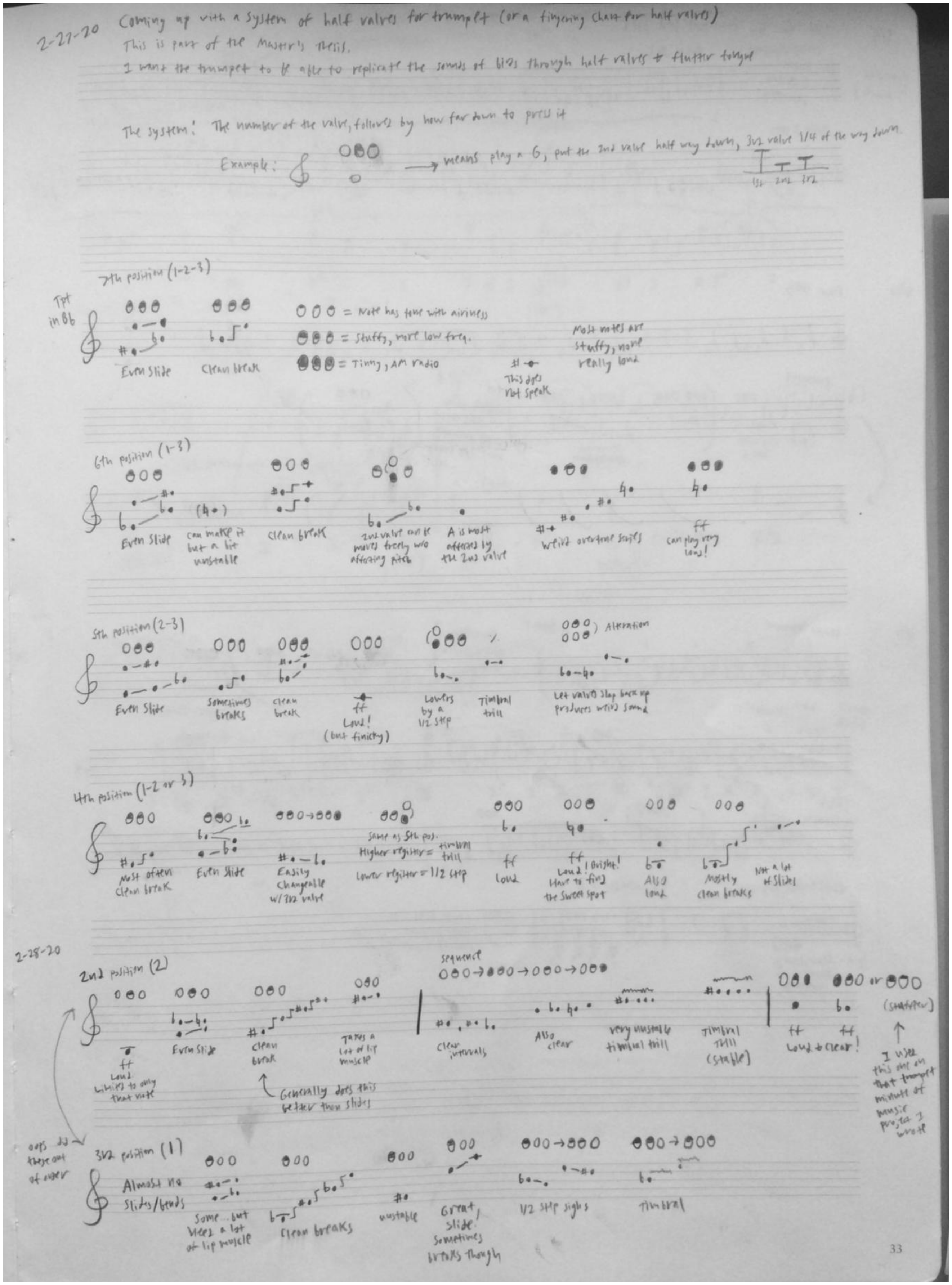
The trumpet solo is the only event in *Currents* tied to an animal instead of a weather event. Metaphorically, the bird is used to represent "our last, best connection to a natural world that is otherwise receding" and serves as an alarmed messenger of the destructive power of the weather events depicted throughout *Currents.*[37] This event is also a celebration of music and bird song, a relationship that has been explored by a long lineage of composers throughout music history.[38] My approach to bird song began with re-inventing the relationship with my primary instrument (the trumpet) and creating a comprehensive catalogue of half-valving techniques for the instrument (Example 45).

---

[37] Jonathan Franzen, "Why Birds Matter, and Are Worth Protecting," *National Geographic*, January 2018, https://www.nationalgeographic.com/magazine/2018/01/why-birds-matter/

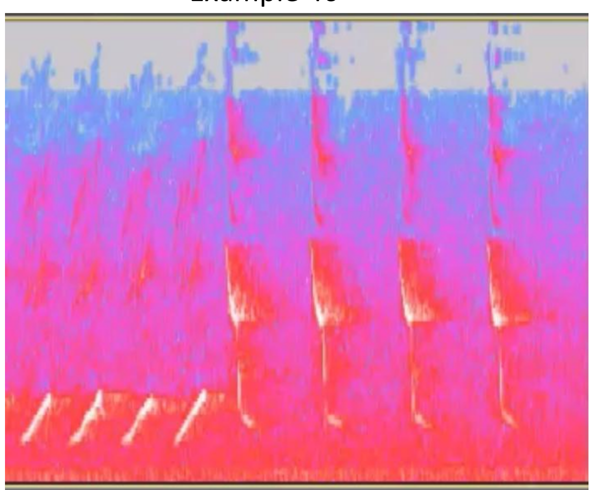
[38] Some examples: Handel's "Organ Concerto No. 13: The Cuckoo and the Nightingale" (1739), Respighi's "Gli uccelli (The Birds)" (1928), Bartok's "Piano Concerto No. 3" (1945), Messiaen's "Catalogue d'oiseaux" (1959), Luther Adams' "songbirdsongs" (1974-80)

Example 45

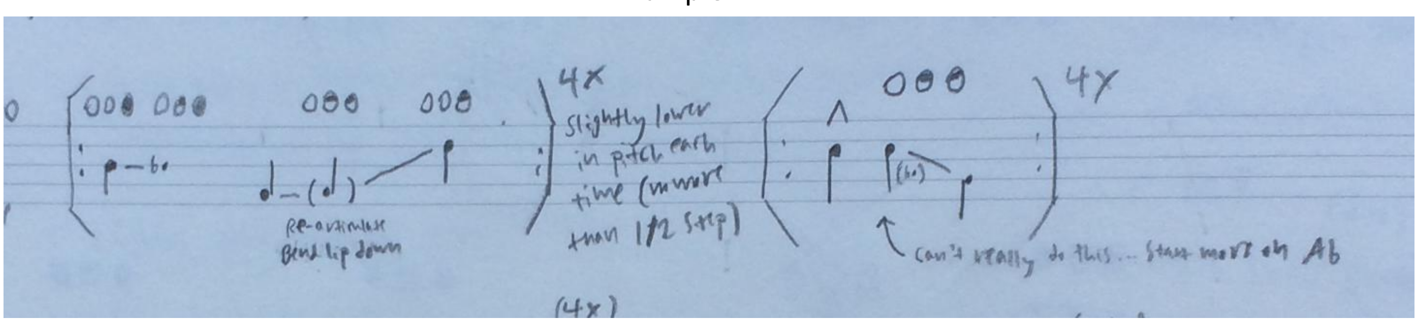

2-27-20 Coming up with a system of half valves for trumpet (or a fingering chart for half valves)
This is part of the Master's thesis.
I want the trumpet to be able to replicate the sounds of birds through half valves + flutter tongue
The system: The number of the valve, followed by how far down to press it
Example:
means play a G, put the 2nd valve half way down, 3rd valve 1/4 of the way down
1st 2nd 3rd
7th position (1-2-3)
Tpt in Bb
Even slide
Clean break
= Note has tone with airiness
= stuffy, more low freq.
= Tinny, AM radio
This does not speak
Most notes are stuffy, not really loud
6th position (1-3)
Even slide
can make it but a bit unstable
Clean break
2nd valve can be moved freely w/o affecting pitch
A is most affected by the 2nd valve
weird overtone scales
ff
can play very loud!
5th position (2-3)
Alteration
Even slide
Sometimes breaks
clean break
ff
Loud! (but finicky)
Lowers by a 1/2 step
Timbral trill
Let valve slip back up produces weird sound
4th position (1-2 or 3)
Most often clean break
Even slide
Easily changeable w/3rd valve
Same as 5th pos.
Higher register = timbral trill
Lower register = 1/2 step
ff
Loud
ff
Loud! Brighter! Have to find the sweet spot
Also loud
Mostly clean breaks
Not a lot of slides
2-28-20
2nd position (2)
sequence
ff
Loud
Limited to only that note
Even slide
Clean break
Takes a lot of lip muscle
Generally does this better than slides
Clear intervals
Also clear
very unstable timbral trill
Timbral trill (stable)
or
(stuffier)
ff ff
Loud + clear!
I used this one on that trumpet minute of music project I wrote
oops these are out of order
3rd position (1)
Almost no slides/breaks
Some... but needs a lot of lip muscle
Clean breaks
unstable
Great slide! Sometimes breaks though
1/2 step sighs
Timbral
33

Next, I chose eight[39] different birds found in my home state of Michigan (American Robin, Blue Jay, Cardinal, Chickadee, Hermit Thrush, House Finch, House Sparrow, Red Bellied Woodpecker) and studied recordings from the Audubon's Guide to North American Birds. The recordings were often transposed lower and time-stretched in order to achieve a clearer analysis. In addition to transcribing pitch, I utilized my catalogue of half valve trumpet techniques to transcribe more timbral elements of the bird song. A comparison of the spectrogram of a Cardinal and my trumpet transcription can be seen below (Example 46 and 47).

Example 46



Example 47



[39] The number eight is significant in this piece, with 1998 being the 80th anniversary of the Migratory Bird Treaty Act

Once these trumpet transcriptions of the eight birds were complete, I isolated 21 different fragments to use as the basis for the musical phrases in the trumpet solo. I spread these fragments across two pages of music, the formal structure of the piece visually resembling a forest with different pockets of sound worlds across the entire landscape. The trumpet player is given the direction to "choose your own adventure" through the gestures, making each iteration of the piece highly improvisatory and varied.

The trumpet player is also directed to play one gesture about every five seconds. Max/MSP records the trumpet in these five second intervals, playing back fragments of the trumpet sound at random. Playback of these trumpet fragments are recalled at twice their normal speed and transposed up an octave (by controlling the "sig~" rate on a "groove~" object) to further resemble the quality of bird song; I also uses a complex vocoder[40] to create glitchy, ghostly copies of the trumpet sound, an uncanny electronic counterpart that ominously grows as the piece continues on (Example 48). Real recordings of the eight birds are also used in the piece, always played in the same order as contrapuntal activity against the more improvised elements of the trumpet part. A recording of a hermit thrush, a bird whose mystical bird call is further etherealized with reverb and delay effects, enters to signify the end of the piece.

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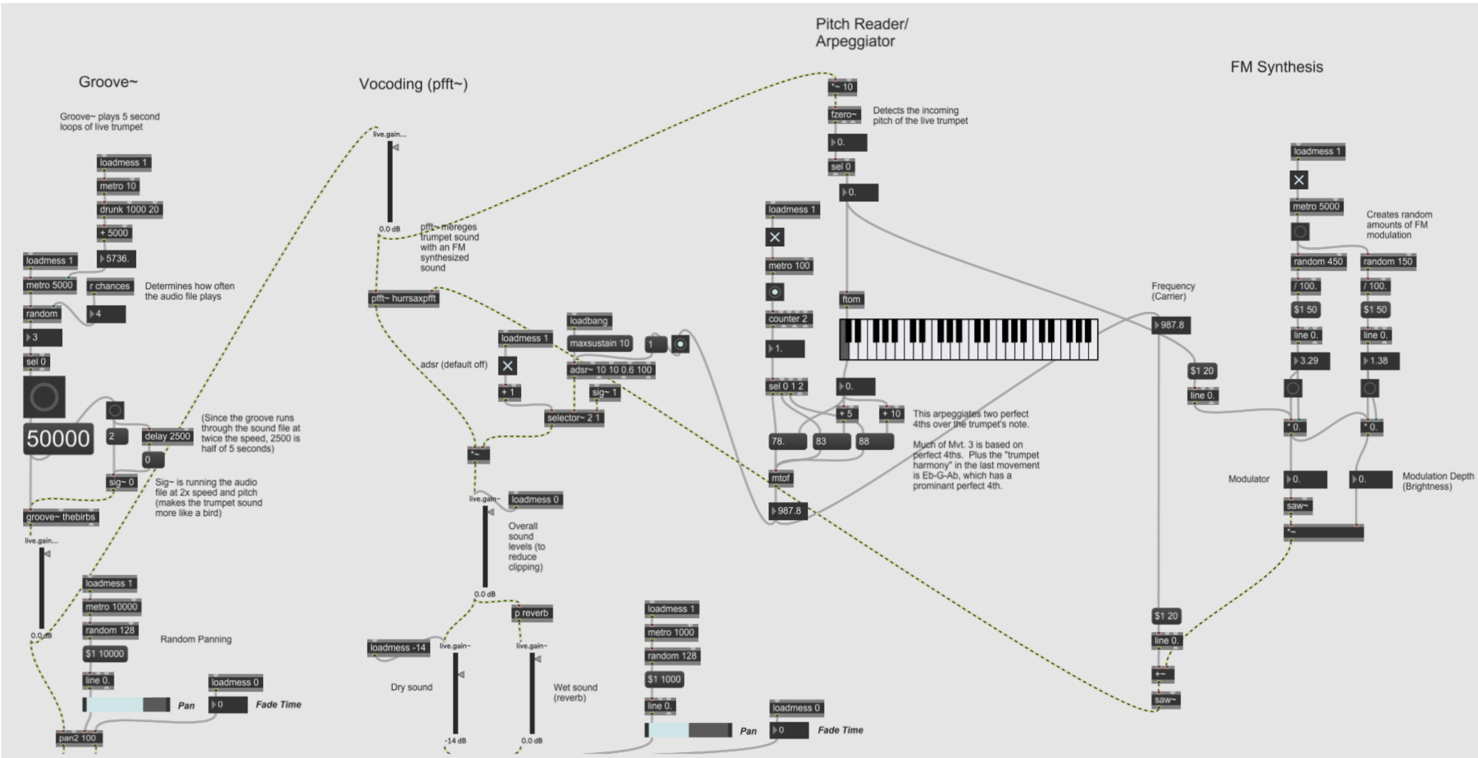
[40] A "retune~" object analyzes the pitch of the incoming trumpet sound, arpeggiates two perfect 4ths on top of it, sends this pitch information to a "saw~" object, applies heavy amounts of FM synthesis, then vocodes all of this with the live trumpet sound using a "pfft~" object. Delay and panning are also randomly applied at the end of the process.

Example 48: “birbs” subpatch

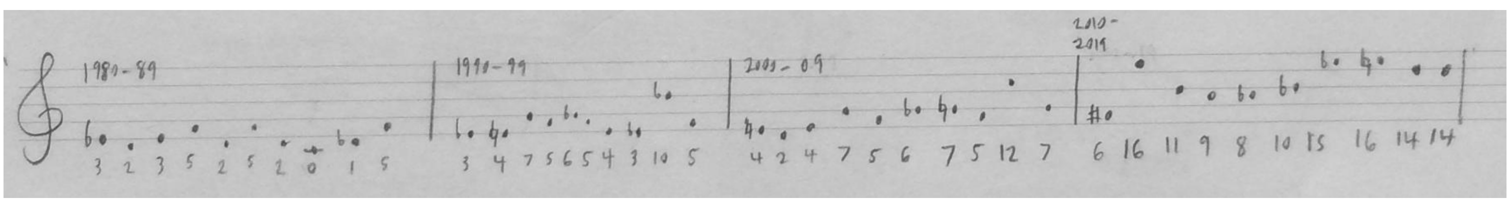


After the trumpet bird event, the first major climactic moment of *Currents* occurs. The year 1998 was the first year to reach ten billion-dollar weather events in one year. Max sonifies ten different pitches to swell in with all eight instruments in the octet. At the top of the swell the instruments break into a flurry of extended techniques, creating a sound world that functions simultaneously as a reprise of the trumpet’s bird event (air, keys, crowing) and as an premonition to siren-like gestures that will develop in later movements (glissandos and rips).

Movement 4 (2000-2009)

With Movements 2 and 3 establishing a mode of sonification that resulted in music that was more aleatoric and gestural, I wanted the next movement to feel more traditionally composed. Movement 4 sonifies counterpoint between the instruments, long melodic phrases with varied rhythms, and detailed background accompaniment. I started by returning to a large-scale perspective on the data. I took all forty data points for the number of weather events each year and sonified them using integer notation to determine pitch (Example 49). After creating this pitch outline, I went through and created a melody by inserting octave displacements, cued notes, and a variety of rhythms (Example 50). None of these elements were data driven and were chosen simply for musical reasons.

Example 49



Example 50

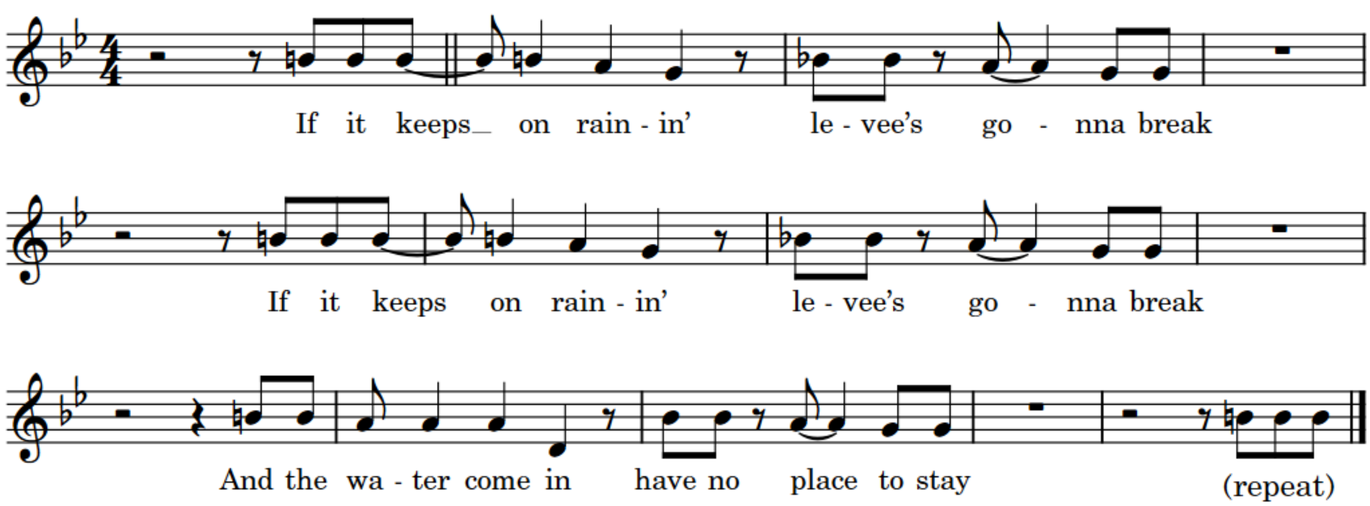
In a nod to the second movement of Stravinsky's "Octet for Wind Instruments," the solo oboe introduces the main melody. The horn and trombone enter in canon, transposing the melody down by a specific interval. These entrances, as well as subsequent entrances of the melody, are transposed in relation to the weather data. The number of weather events in the years covered in this movement (2000-2009) is utilized loosely as data for transposition: 4-2-4-7-5-6-7-5-12-7. Below is an outline up until the saxophone event that shows how these transpositions occur:

- Ms. 2, horn, up 4 semitones
- Ms. 4, trombone, down 2 semitones
- Ms. 6, fl/sax, up 7 semitones
- Ms. 16, cl/tpt, down 6 semitones
- Ms. 21, fl/sax, untransposed (12 semitones)
- Ms. 26, unison, down 1 semitone (this number breaks from the data)

A few other details in the first half of this movement worth mentioning. The percussive chimes serve as a demarcation of each year in the data (e.g. 2000, 2001). There are several small references to the ascending scale from Movement 2 (ms. 8, 13-15, 21), as well as the perfect 4ths found in Movement 3 (ms. 10, 19-20). Also, the "siren" motive begins to develop a bit more in the trombone (ms. 13-15, 23-29) and comes back as a central feature of Movement 5.

Measure 26 marks a strong rise in intensity as the octet makes a unison statement of the melody, serving as preparation for the centerpiece of the movement: the saxophone event depicting Hurricane Katrina. Not only is Hurricane Katrina the costliest ($167 billion) and second deadliest (1,833 lives, only behind Hurricane Maria in 2017) weather disaster in the last 40 years, but it also proved to be a catalyst for feelings of racial inequality in America.[41] This lead to the saxophone event being the most nuanced and richly layered solo event in *Currents*, mapping layers of historical narrative (the vocal sample from Spike Lee's "When the Levees Broke") and cultural narrative (the use of the 1929 blues song "When the Levee Breaks," see example 51).

Example 51: "When the Levee Breaks" written by Kansas Joe McCoy and Memphis Minnie

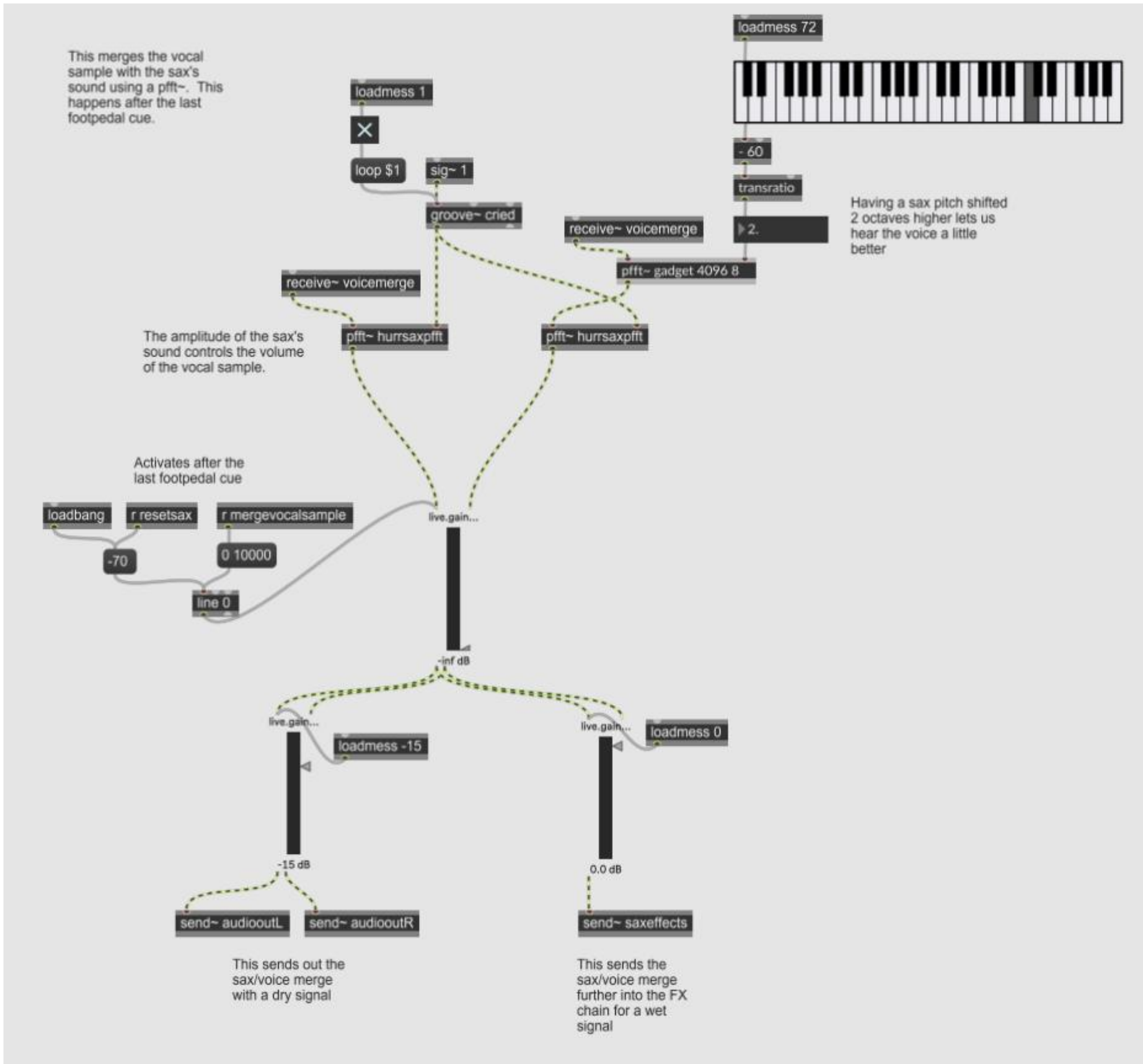


[41] See Jamelle Bouie, "Where Black Lives Matter Began: Hurricane Katrina Exposed our Nation's Amazing Tolerance for Black Pain," *Slate*, August 23, 2015, https://www.nationalgeographic.com/magazine/2018/01/why-birds-matter/. For a more in depth study, see Ismail K. White, et al., "Feeling the Pain of My People: Hurricane Katrina, Racial Inequality, and the Psyche of Black America," *Journal of Black Studies* 37, no. 4 (March 2007): 523-538.

A swung eighth-note style with notated jazz articulations is adopted as an emulation of the blues style from "When the Levee Breaks." The imagery of swirling winds guided the two main motives used throughout the solo event. The melody of "When the Levee Breaks" is presented in all twelve keys throughout the solo event, while the saxophone opens with the "trill motive," an interruptive gesture that often intercuts this melody. Measures 43-47 is an "eye of the hurricane" moment where the saxophone's extended technique (air blown through the instrument and key slaps) and the sudden shift in dynamics/tempo are used to create musical contrast from the intensity of the previous sections. The full octet enters in measure 57 to add more power behind the saxophone soloist as the event comes to an end.

The foundation for the Max/MSP patch used for this solo event is derived from a previously discussed patch from Part 1 of this paper (Hurricane Katrina Tracker Patch #4). Given this, I will only point out the changes and additions that were made in the creation of this patch. Although the use of the vocal sample in the original patch proved to be unsuccessful, a few changes were made in this patch to make it more sonically cohesive. Instead of being fed through a granular synthesizer, the sample was now directly connected with the amplitude of the saxophone's sound using a "pfft" object to vocode the two together. In other words, the vocal sample is only heard when the saxophone's sound is picked up by the microphone. Example 52 shows the vocoder below.

Example 52



The vocal samples were also inserted in their entirety at the beginning of the solo, triggered by a foot pedal or switch by the saxophone player. This gives the listener a chance to hear the vocal sample as a separate entity before it is sonically merged with the saxophone player. The text of the vocal sample is printed in full below:

> You know in days after Katrina, many…many of us cried. I am not afraid to say that I cried because I was sad about what I was seeing. And I cried because people were losing their lives. And I cried because there was such chaos. And I cried because I felt helpless and I didn't know what I could do.[42]

Slight additions were also made to the effects processing of the live saxophone sound. The use of the "degrade~" object was still utilized to de-sample the sound as the data traveled through the hurricane's category strength numbers. Instead of using delay effects, panning effects are used that accelerate the sax sound's motion from speaker to speaker as the wind speed data gets higher. In addition, a background "sound swell" is created from heavy reverb and low pitch shifting treatment on the saxophone's sound. The volume level of this "sound swell" is controlled by pressure data from the hurricane (lower pressure equates to stronger storms, meaning a louder "sound swell").

After the saxophone event is finished, the full octet enters in measure 35 as a shrieking response to the trauma caused by Hurricane Katrina. The dissonant pitch material is a simultaneity of the scale found in Movement 2 (Bb-Db-D-E-F-Gb-A). The intensity subsides as the data moves through the 2006 and 2007 data, years where a decrease in the number of weather events (seven and five, respectively) provides a brief respite. All the while, the instruments quote small, dissonant fragments from the melody introduced at the beginning of the movement. A climactic swell with a dramatic trombone "siren glissando" builds in measures 40-41 as the data makes its way through the year 2008 (which experienced 12 weather events, the highest in the data up until this point). The energy again subsides, with a brief quotation of Movement 2 introducing the last five measures of the movement. The

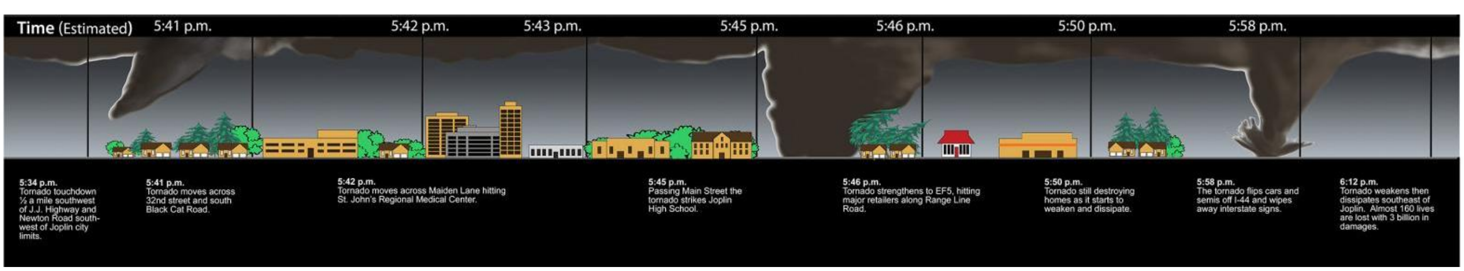
[42] Damon Hewitt (Assistant Counsel NAACP Legal Defense Fund, New Orleans Native), as featured in *When the Levees Broke: A Requiem in Four Acts*, Dir. Spike Lee, 40 Acres and a Mule Filmworks, 2006. Timestamp is 55:37 in the movie.

trumpet plays one final iteration of the movement's main melody. The third and second to last measures (m. 45-46) segment the melody into three note fragments, while the last measure (m. 47) truncates it into two notes. This two-note motive provides a direct segue to the flute's opening two notes of the next movement.

Movement 5 (2010-2019)

Movement 5 begins with a nimble, seven measure introduction that haphazardly expands and contracts the opening two note motive. The flute decides on a three note motive to launch itself into the tornado solo event. The pitches of this three note motive were sonified using their corresponding MIDI note values from the timestamp of when the Joplin tornado touched down (5:34 pm, 5-3-4 = F-D#-E). This also guided the sonification at the end of the piece, with measures 34-36 depicting the timestamp when the tornado finally dissipates (6:12 pm, 6-1-2 = F#-C#-D). The example below shows the timeline of the tornado's path from a document provided by the NOAA and the National Weather Service (Example 53).

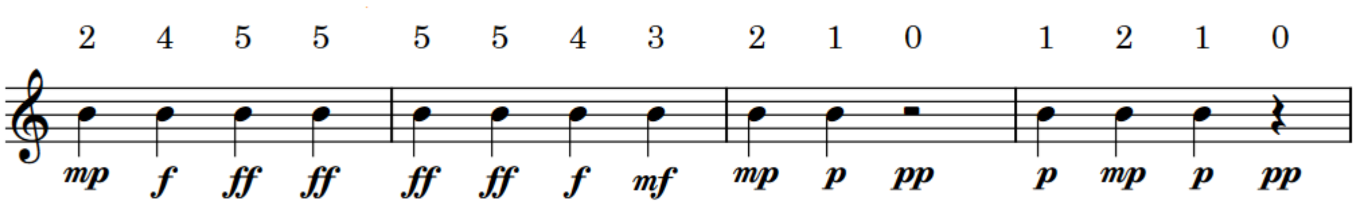
Example 53



Next, the dynamics of the piece were derived from the strength of the tornado over time using the Enhanced Fujita scale. Lower Fujita scale ratings corresponded to lower dynamics (EF1 = piano) and vice versa (EF5 = fortissimo). The first example below (Example 54) shows the path of the tornado mapped with its EF-Scale rating over time. The second example below (Example 55) shows this data sonified into notation, with the EF-Scale ratings on top and the dynamics on bottom. This second example also showcases the basic structural outline of the entire flute solo event.

Example 54

Example 55



The EF-Scale data was also used to sonify pitch elements by looking at the wind readings for each EF-Scale rating (i.e. EF0 = 65-85 mph, see Example 56) and using MIDI note values to translate them into pitch (65-85 could be 65 = F and 85 = Db, but it could also be 6 = F#, 5 = F, 8 = Ab, 5 = F). These formed motivic cells that were then used to freely compose the flute event (Example 57).

Example 56

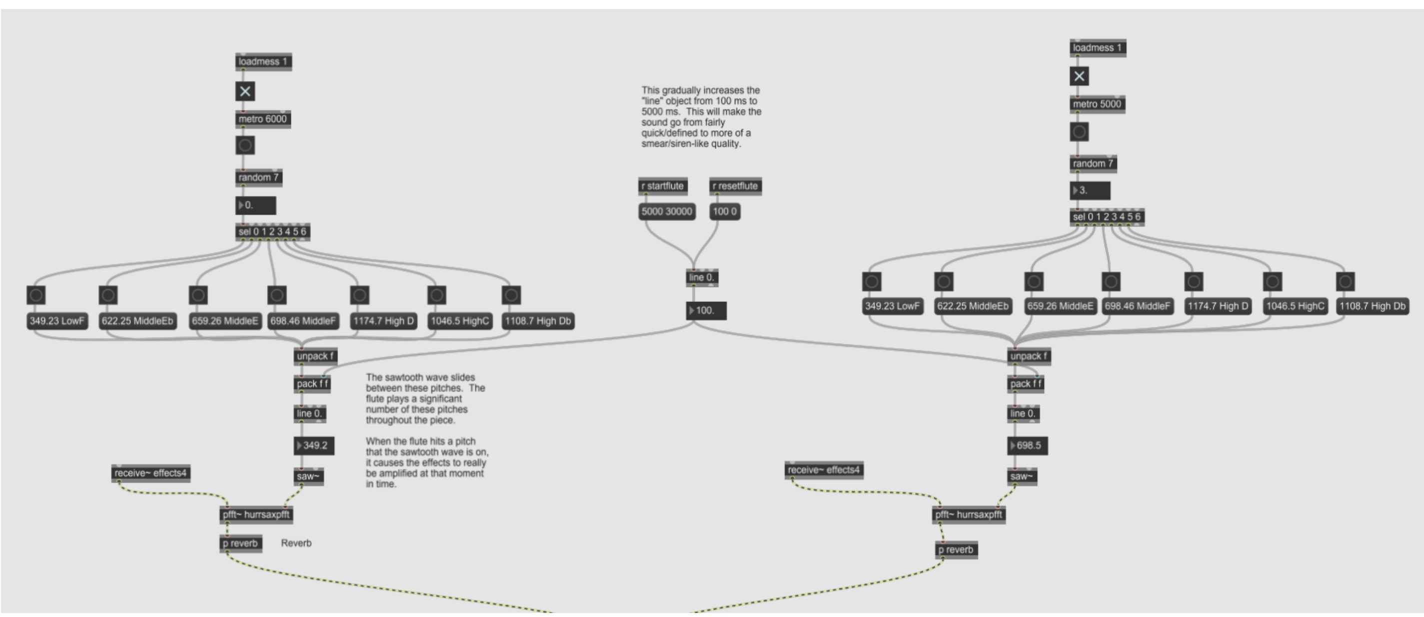
Enhanced Fujita Scale

EF0	65–85 mph	Light damage
EF1	86–110 mph	Moderate damage
EF2	111–135 mph	Considerable damage
EF3	136–165 mph	Severe damage
EF4	166–200 mph	Devastating damage
EF5	>200 mph	Incredible damage

Example 57

To strengthen the imagery of the tornado-like 16th note patterns in the notated flute part, Max/MSP provides a soundscape akin to a tornado warning siren. A sawtooth wave ("saw~" object) gradually sliding up and down in pitch is merged with the flute sound (vocoded with a "pfft~" object) to create this effect. These pitches of the sawtooth wave were chosen as pitches that appear frequently throughout the notated flute part; when the live flute and the sawtooth wave happen to land on the same pitch, the siren effects are amplified at that moment in time (Example 58)

Example 58



A full octet gesture in measures 7-8 ascends to rebuild from the rubble left in the flute event. The pitch material here is loosely constructed around the interval of a perfect 4th that was featured prominently in Movement 3. The gesture fails, toppling over into the dissonant, aleatoric section from measures 9-13. It is worth noting that in measure 9, each instrument provides the first true glimpse of the harmonic structures that have been embedded as miniscule fragments during the previous solo events. These structures will come to full fruition in Movement 6 and will be discussed in more detail at that time. A gradual rhythmic augmentation occurs over the course of measures 9-13, most clearly shown in the percussion's expansion from a three-note motive (ms. 9-10) to a four (m. 11) and five-note motive (m. 12-13). This serves as a preparation for the quintuplets featured throughout the upcoming percussion event. Measure 13 provides a clear allusion to the end of Movement 2 with its pitch material (here the scale is descending instead of ascending) and the glacial slowing of tempo.

As discussed in Part 1 of this paper, a concern when working with data is the impersonal distance between the one accessing the data and the one affected by it. The saxophone event attempted to bridge that gap by including a vocal sample, a personal narrative from someone directly affected by the events of Hurricane Katrina. In that vein, I wanted to make sure to include something in *Currents* that personally affected *me,* an acknowledgement of the humanity hiding behind the impersonal nature of the weather data. Before I share my experience, it is important to note that mine pales in comparison to those who have suffered through much more traumatic weather events. Below is a brief account of my experience with the 2014 Detroit flood:

> I have only been afraid of water one time in my life. On August 11th, 2014, I was casually driving home as the second wettest rainfall in Detroit's history was descending from the sky. After convincing my wife to drive across our front lawn to escape the encroaching flood waters on our house, I remember calling my mother on the phone and pleading with her to check the weather radar: "When is this going to end?", knowing that she was 200 miles away and could do very little to help. After the storm subsided, I will never forget the eerie image of a car floating in a massive rain puddle just a block away from our house. I will also never forget that week's trash collection, the contents of people's basements emptied onto the curb in what seemed less like my neighborhood and more like a warzone.

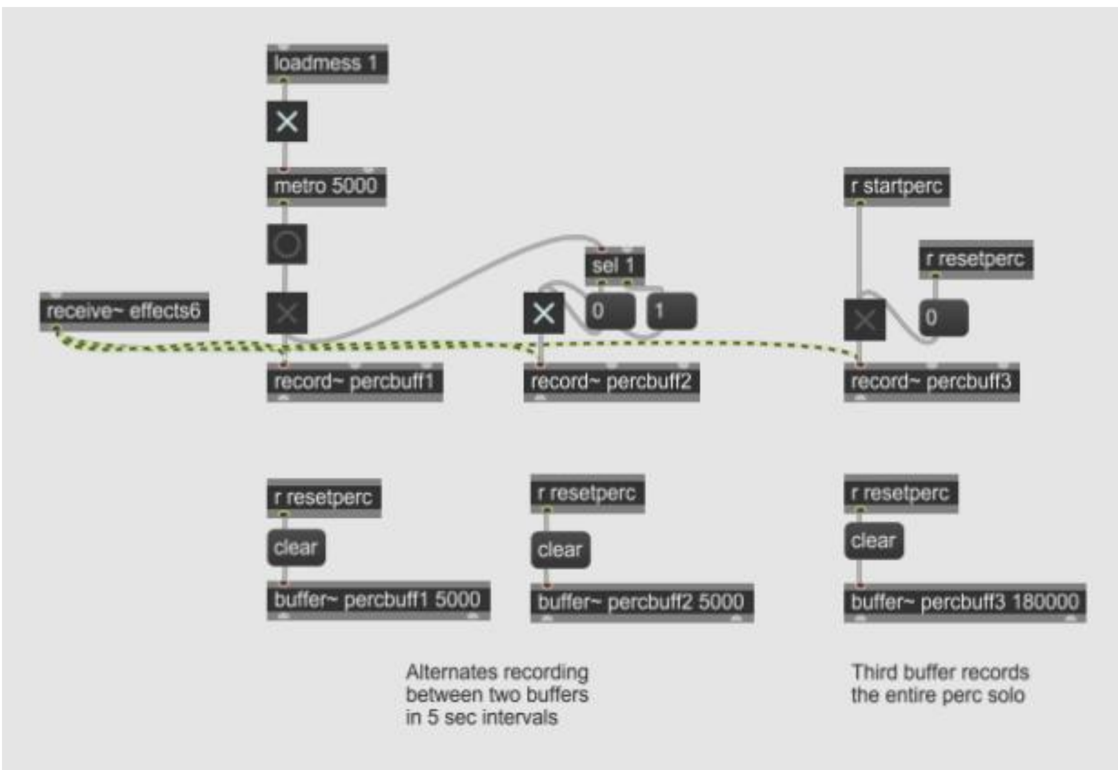
The rising anxiety I experienced during the event became tied to an image of gradually rising flood waters. I imagined the percussionist beginning with tiny droplets of sound and ending in a sonic torrent, aided by the gradual addition of more and more instruments over time. The number five became central to the movement since five inches of rain fell on Detroit over a roughly five hour time span. Thus, five percussion instruments were employed in the piece and quintuplets became the guiding rhythmic motive. Using hourly precipitation amounts sourced from the Weather Underground, I mapped out the rate of rainfall and projected this timeline overtop the 31 measures I allotted for the piece (Example 59). Every time an inch of rain was recorded, another percussion instrument was added (in order: snare, chimes, cymbal, bass drum, toms).

Example 59: Page 2 of 3 from the Daily Observations report on the Weather Underground

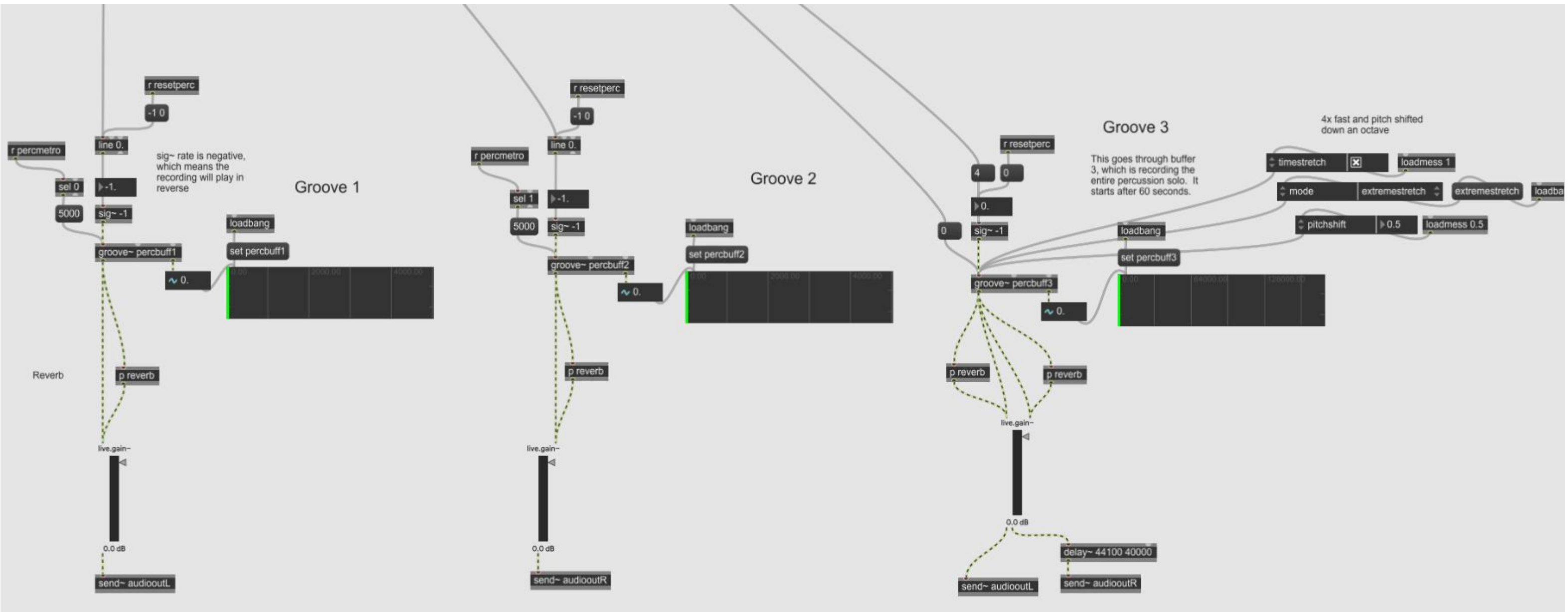
Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
6:16 PM	71 °F	68 °F	90 %	ENE	13 mph	0 mph	29.07 in	0.2 in	Heavy T-Storm
6:23 PM	71 °F	68 °F	90 %	E	10 mph	0 mph	29.08 in	0.5 in	Heavy T-Storm
6:38 PM	71 °F	68 °F	90 %	ENE	12 mph	0 mph	29.06 in	1.1 in	Heavy T-Storm
6:47 PM	72 °F	68 °F	88 %	ENE	15 mph	0 mph	29.06 in	1.2 in	Heavy T-Storm
6:51 PM	72 °F	68 °F	88 %	NE	13 mph	0 mph	29.05 in	1.2 in	T-Storm
6:53 PM	71 °F	68 °F	90 %	ENE	12 mph	0 mph	29.04 in	1.2 in	T-Storm
7:02 PM	71 °F	68 °F	90 %	NE	8 mph	0 mph	29.04 in	0.1 in	Heavy T-Storm
7:07 PM	71 °F	68 °F	90 %	CALM	0 mph	0 mph	29.04 in	0.2 in	Heavy T-Storm
7:14 PM	71 °F	68 °F	90 %	VAR	6 mph	0 mph	29.04 in	0.3 in	Heavy T-Storm
7:22 PM	72 °F	68 °F	87 %	SE	8 mph	0 mph	29.04 in	0.4 in	T-Storm
7:33 PM	72 °F	69 °F	91 %	SSW	10 mph	0 mph	29.03 in	0.5 in	Heavy T-Storm
7:45 PM	72 °F	68 °F	87 %	SE	13 mph	22 mph	29.02 in	0.9 in	Heavy T-Storm
7:49 PM	72 °F	68 °F	88 %	S	8 mph	22 mph	29.02 in	0.9 in	Heavy T-Storm
7:53 PM	72 °F	69 °F	91 %	SSE	10 mph	0 mph	29.02 in	0.9 in	Heavy T-Storm
8:05 PM	72 °F	68 °F	87 %	SW	10 mph	0 mph	29.01 in	0.1 in	Light Rain with Thunder
8:14 PM	72 °F	68 °F	87 %	SW	17 mph	22 mph	29.01 in	0.1 in	T-Storm
8:24 PM	72 °F	68 °F	87 %	WSW	14 mph	23 mph	29.02 in	0.1 in	Light Rain
8:53 PM	71 °F	67 °F	87 %	WSW	10 mph	0 mph	29.02 in	0.1 in	Cloudy
9:25 PM	71 °F	66 °F	84 %	W	6 mph	0 mph	29.02 in	0.0 in	Mostly Cloudy
9:53 PM	71 °F	66 °F	84 %	WSW	7 mph	0 mph	29.02 in	0.0 in	Mostly Cloudy
10:13 PM	70 °F	66 °F	87 %	W	10 mph	0 mph	29.02 in	0.0 in	Mostly Cloudy
10:46 PM	70 °F	65 °F	84 %	W	8 mph	0 mph	29.03 in	0.0 in	Mostly Cloudy
10:53 PM	70 °F	65 °F	84 %	W	8 mph	0 mph	29.03 in	0.0 in	Mostly Cloudy

Max/MSP continually records the percussion's sound using three "buffer~" objects (Example 60). Two of the buffers trade off recording five-second loops of the percussion sound. These sounds are backmasked (reversed using a negative "sig~" rate on the "groove~" objects) to create rushing waves of sound. The buffers are initially played back at normal speed, but roughly 90 seconds into the solo the two buffers split from each other into double =-speed (and octave up pitch shifting) and half-speed (and octave down pitch shifting) tempos to create multiple "streams" of sound. The third buffer records the percussion solo in its entirety, but does not initiate playback until one minute into the event. At that time, the buffer is played four times speed but transposed down an octave to add more thundering waves of background sound (Example 61).

Example 60



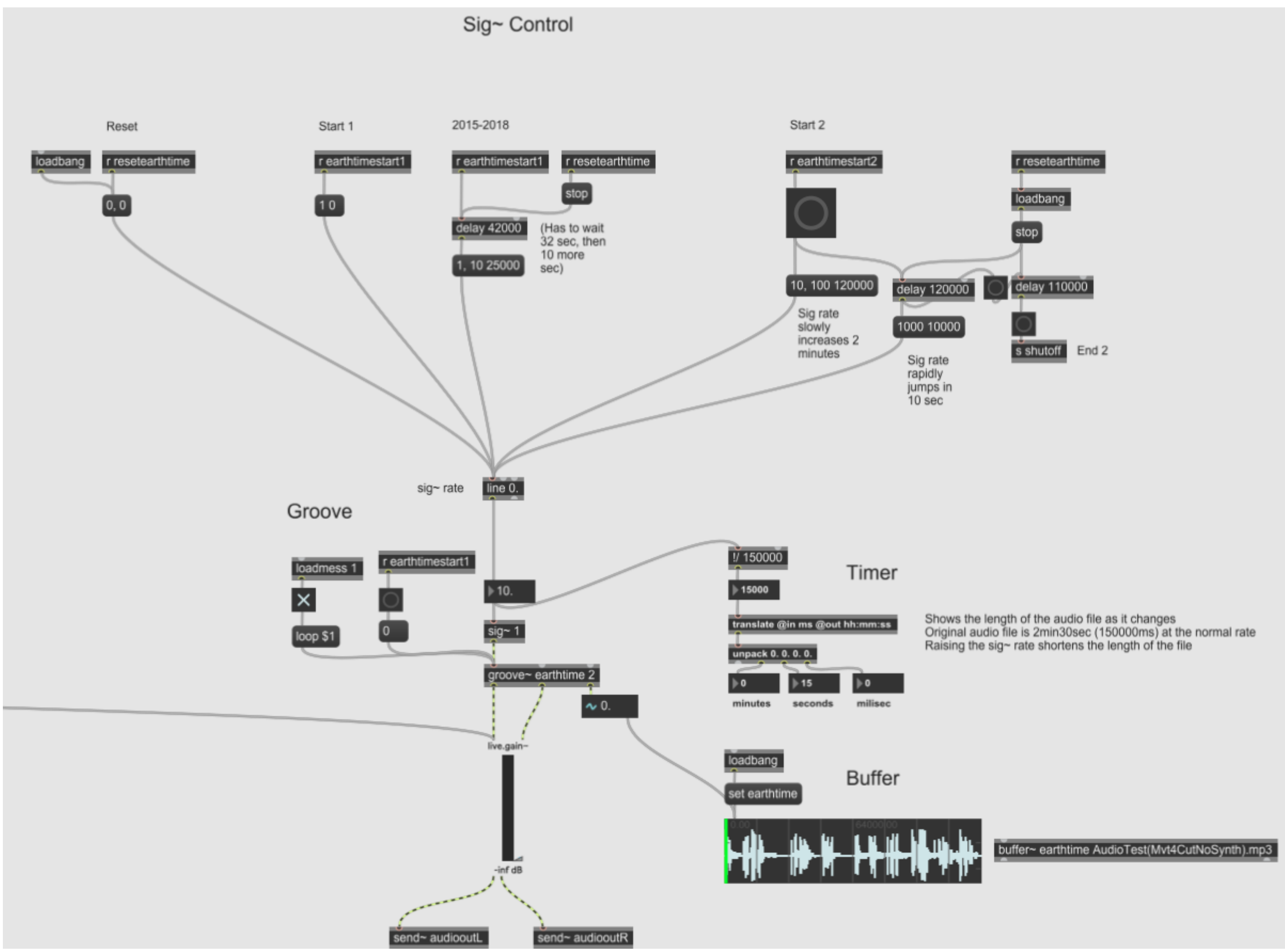
Example 61



Immediately after the percussion event, Max/MSP initiates a reprise of Movement 1. In measure 14, Max performs two gestures (2010 and 2011) of the NOAA sonified data from 2010-2019. The full octet joins the acousmatic sounds in measure 15, playing in a fragmentary style similar to the opening of the movement. Measure 20 represents a summation of several motives heard throughout *Currents*. The melody from Movement 4 exerts a strong presence in measure 20 and receives a second treatment in measure 27 with dissonant intervals and augmentation of the rhythm. Meanwhile, a cascading figure in measure 20 containing the scale pitch material from Movement 2 is passed through the octet. The motive is treated with note augmentation similar to the process seen before the flute and percussion events in this movement; each cell of the motive begins with two notes (m. 20) and expands to three (m. 22) and four notes (m. 24). The interval of a perfect 4th returns from Movement 3, prominent in the section from measures 25-27. Also returning from Movement 3 is the aleatoric extended technique gestures representing birds and sirens in measure 33. As another prescient look at Movement 6, measure 35 outlines harmonies that will be expanded upon later in the work.

As the full octet layers these glimpses of past, present, and future motives on top of each other, Max/MSP begins to alter its temporal perspective on the 2010-2019 data sonified from Movement 1. Between measures 20-33, Max gradually increases the "sig~" rate from 1 (normal speed) to 10 (ten times faster speed and ten times higher pitch), eventually whipping through the 150-second recording in about 15 seconds (Example 62).

Example 62



This represents the zoomed-out perspective of “earth time,” where the decade between 2010-2019 is reduced to a blink of an eye in the context of a 4.5 billion year old planet. The troubling tension between these ideas of “human time” (the live octet gazing over the 40 years worth of data) and “earth time” (Max/MSP whipping through this timeline at astronomical speeds) is perhaps best captured in this emotional quote from a climate researcher:

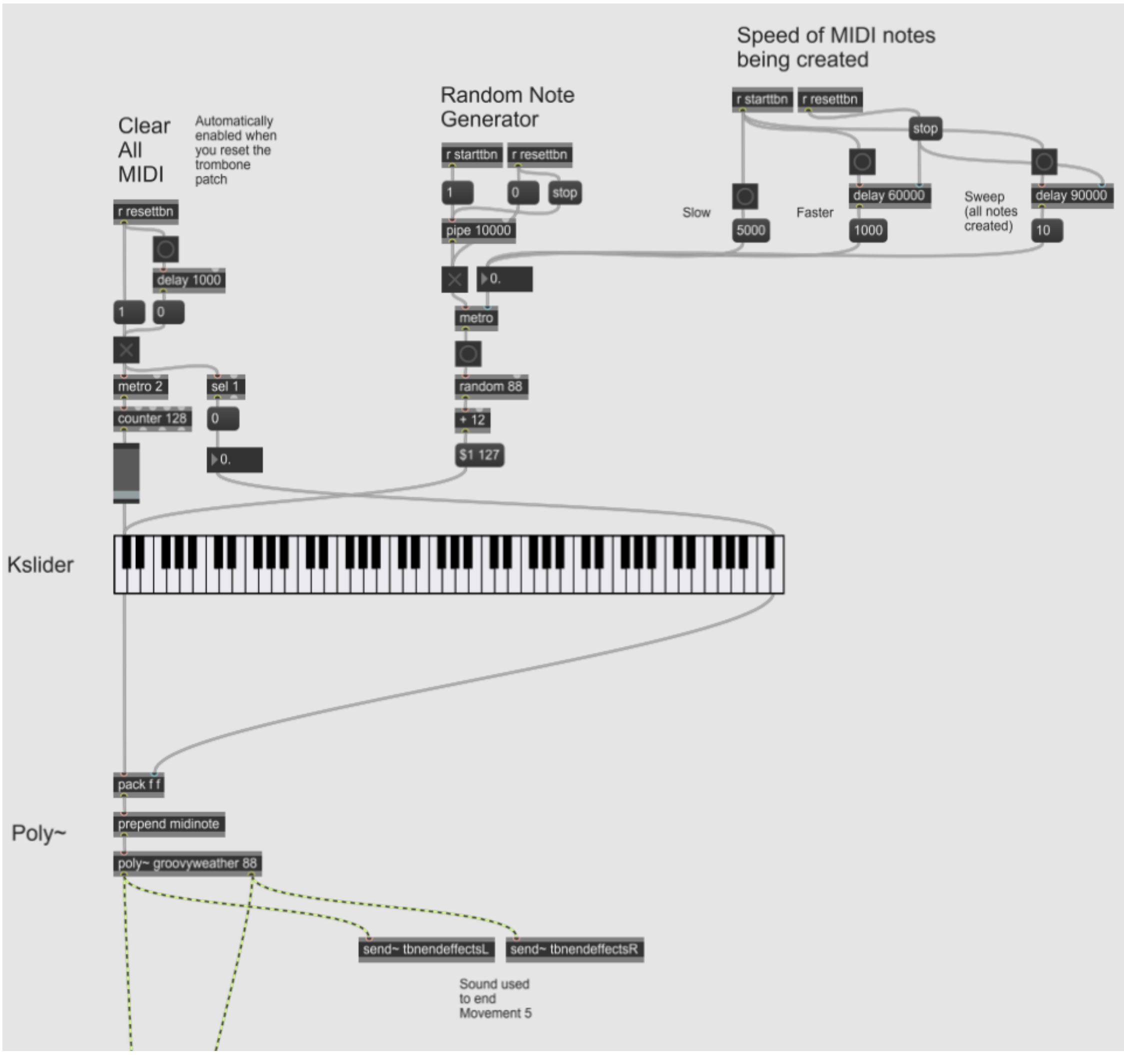
> You know, we could completely screw up the Earth, and it would come back. The problem is, it might not come back for a million years. Now, to the earth, a million years, who cares, it’s nothing. But in human history, you f—ked yourself.[43]

Max/MSP dissipates first, followed by the rest of the octet. As the rest of the instruments kick up a final cloud of sound, the trombone powers through its glissando gestures to lead into the final solo event.

Max/MSP records the opening gesture of the trombone, capturing the initial “spark” of sound that slowly transforms into a sonic wildfire. Max feeds this initial recording into a “poly~” object, gradually creating 88 copies of the gesture at 88 randomized levels of pitch transposition and speed (Example 63). The number 88 is significant due to the 88 lives lost in the town of Paradise, CA as a result of the Campfire Wildfire.

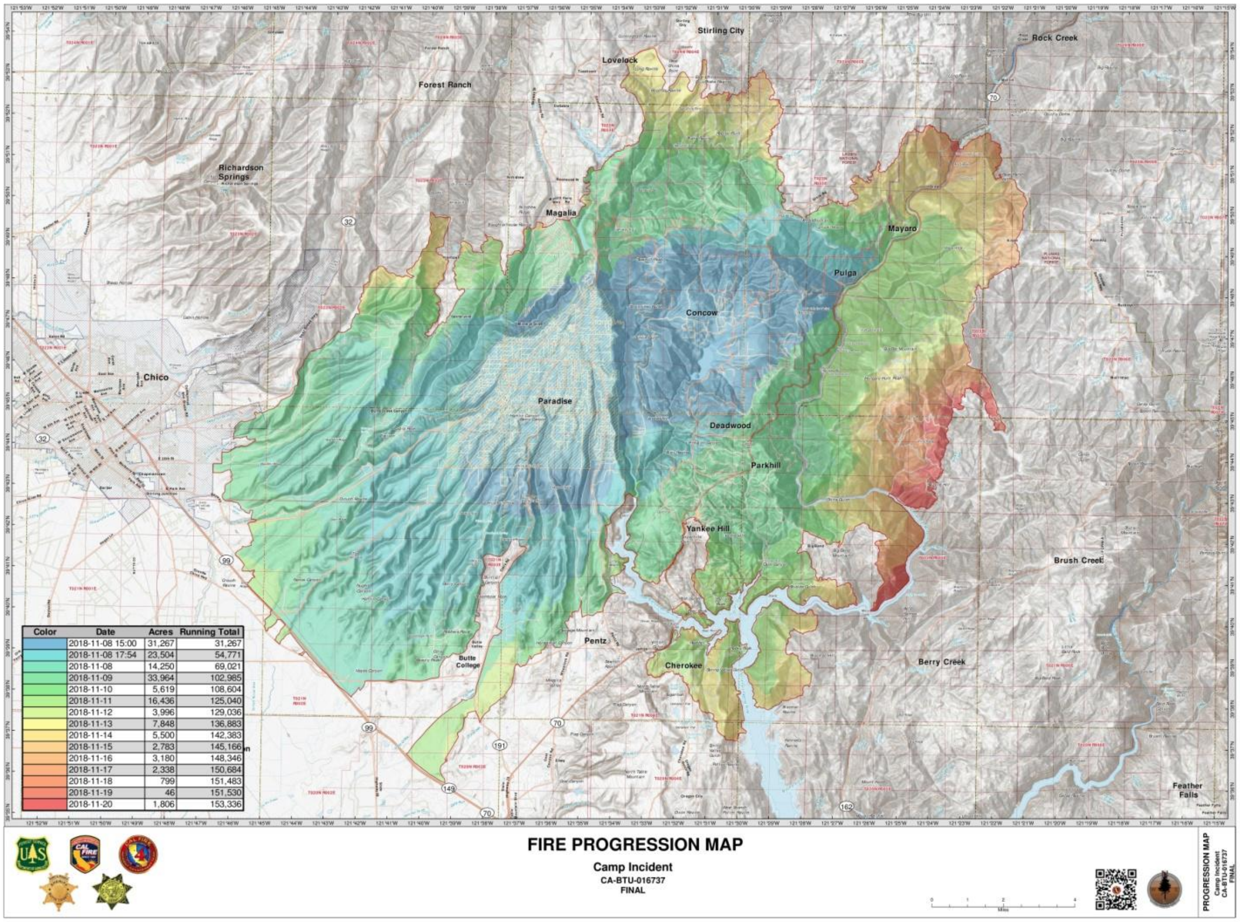
[43] Andrea Polli, *Sonic Antarctica*, Gruen 064, Gruenrekorder, 2009. As quoted from Alexandra Supper, “Sublime Frequencies: The Construction of Sublime Listening Experiences in the Sonification of Scientific Data,” *Social Studies of Science* 44, no. 1 (February 2014): 47.

Example 63



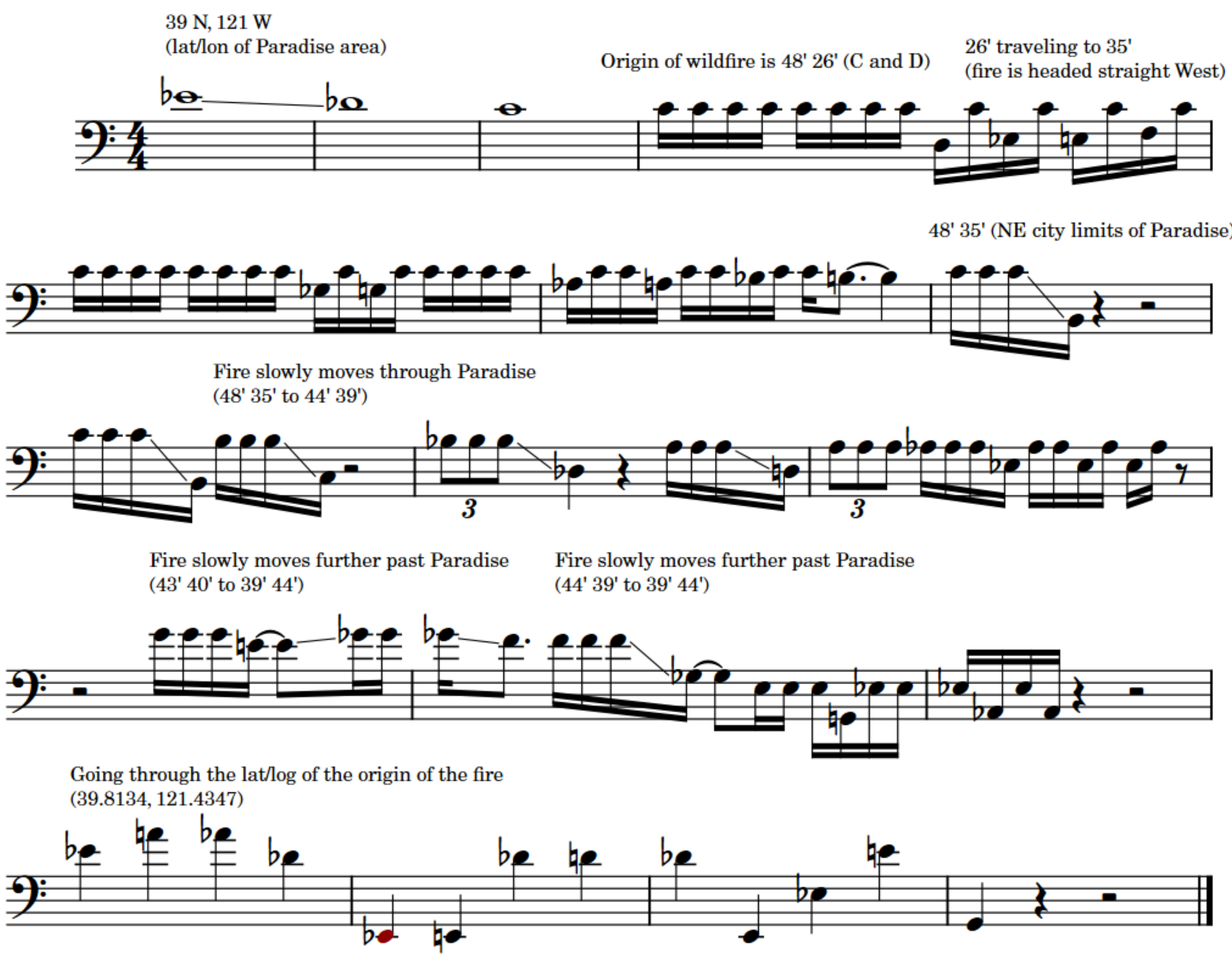
After expanding on the opening motive, the trombone begins playing new material at measure 10. The pitch content was sonified by traveling through various latitude/longitude datasets and translating these geographical journeys into MIDI note values. One of the main resources was a map of the fire's spread taken from the California Department of Forestry and Fire Protection, or CAL FIRE (Example 64).

Example 64



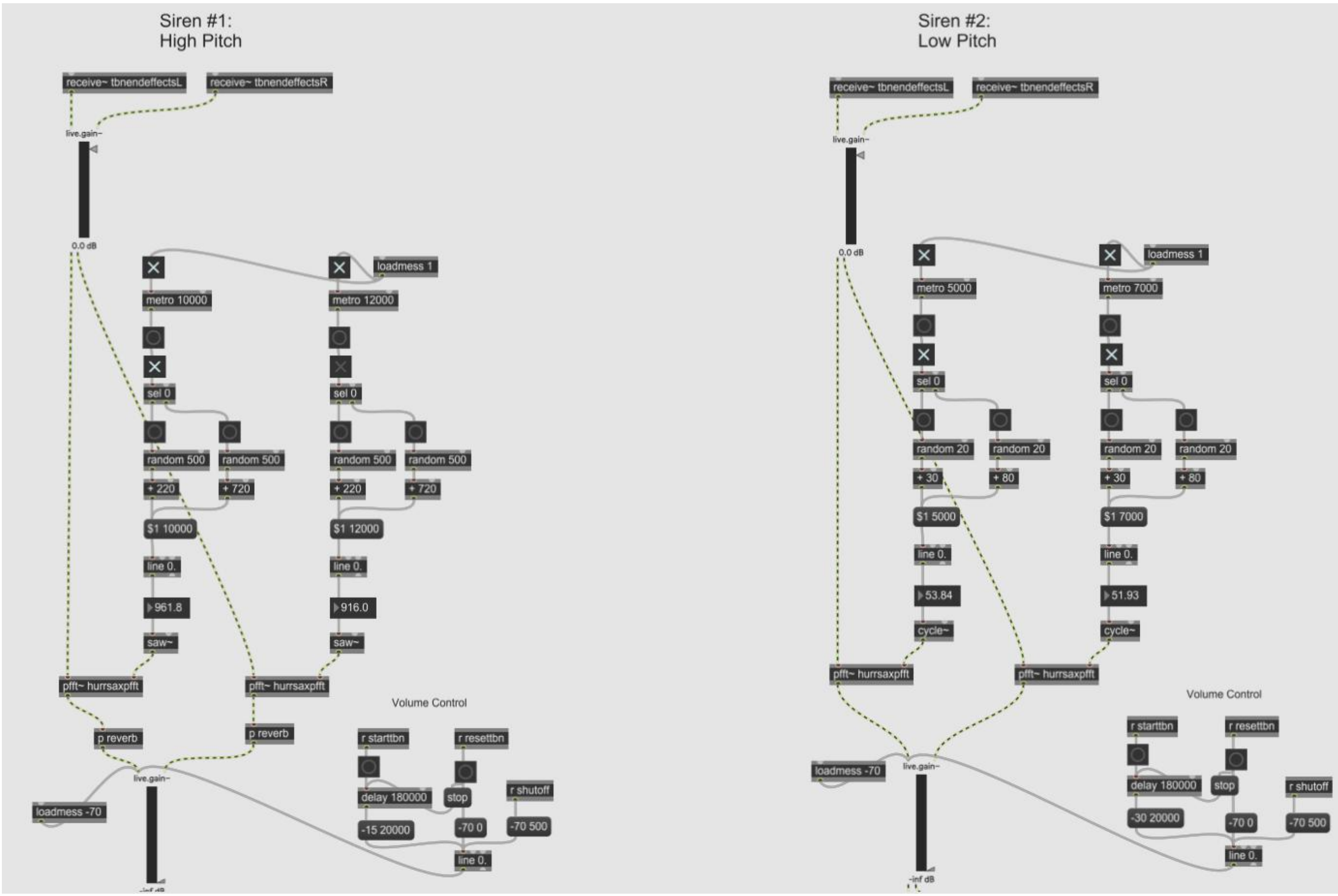
The data starts in Paradise, CA at a lat/lon of 39N/121W (39 = Eb and 121 = Db in ms. 9-10) before the fire starts. The fire's origin emerges at 48N/26W (48 = C and 26 = D in ms. 13) and quickly travels due west (26W proceeds to 35W, the chromatic ascent from D to B in ms. 13-17) and arrives at the northeastern city limits of Paradise at 48N/35W (48 = C and 35 = B in ms. 18). The fire eats through the town of Paradise (48N/35W to 44N/39W, sonified in the collapsing melodic wedge in ms. 21-23) then continues on past Paradise (various lat/lon data points sonified throughout ms. 24-26). In a moment of closure, we travel back to the tragic origins of the fire with even more geographic specificity (39.8134N/121.4347W, ms. 24-32), as if the futile attempt to sharpen the data could offer some explanation for the tragic loss of life. A summary of this pitch information can be seen below in Example 65.

Example 65



At the end of the trombone solo, the “poly~” object quickly sweeps to create all 88 copies of the trombone sound. This wall of white noise is gradually sent through heavy reverb chains (ms. 41) and vocoded with a sawtooth wave for a siren effect (ms. 42, see Example 66). A second layer of noise is created as the wind players gradually join the trombone in creating siren-like effects using extended techniques respective to their instruments. The player’s entrances are theatrical in nature, with each person walking up to the microphone to record their individual sounds. This represents a significant deviation from the rest of the piece, the players previously using the microphone one at a time for their solo events but now all converging on the microphone at the same time. The percussion player joins last, creating a wash of sound with the cymbal as the octet’s final gesture. As one last layer of sound, the “earth time” Max sonification of the 2010-2019 data returns. The 150-second recording begins to take on crackling, percussive qualities as it zips by in as little as a second, the “sig~” rate accelerating past the point of control towards the abrupt end of the movement.

Example 66

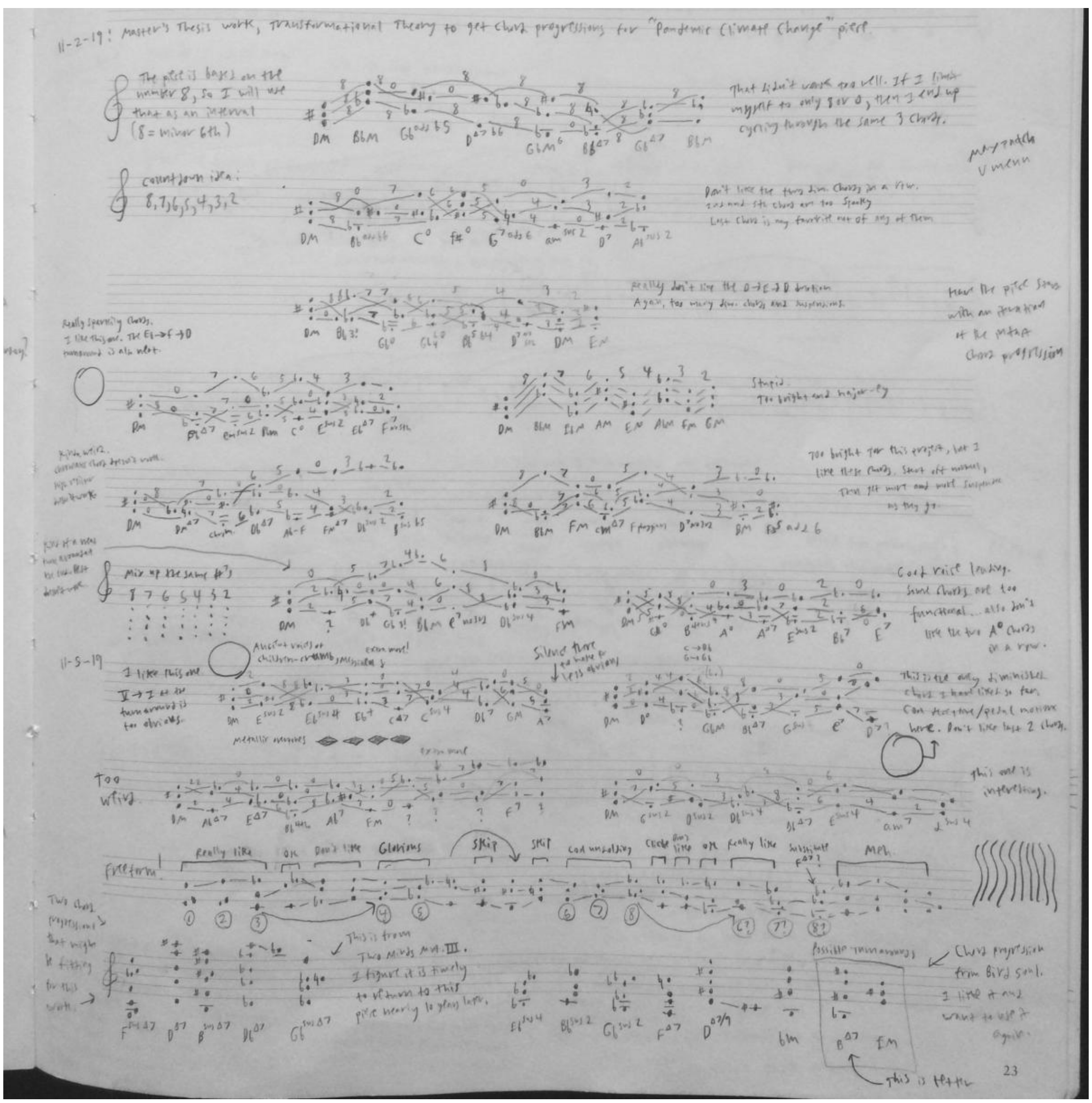


Siren #1:
High Pitch
receive~ tbnendeffectsL
receive~ tbnendeffectsR
live.gain~
0.0 dB
loadmess 1
metro 10000
metro 12000
sel 0
sel 0
random 500
random 500
random 500
random 500
+ 220
+ 720
+ 220
+ 720
$1 10000
$1 12000
line 0.
line 0.
961.8
916.0
saw~
saw~
pfft~ hurrsaxpfft
pfft~ hurrsaxpfft
Volume Control
p reverb
p reverb
r starttbn
r resettbn
live.gain~
r shutoff
loadmess -70
delay 180000
stop
-15 20000
-70 0
-70 500
line 0.
Siren #2:
Low Pitch
receive~ tbnendeffectsL
receive~ tbnendeffectsR
live.gain~
0.0 dB
loadmess 1
metro 5000
metro 7000
sel 0
sel 0
random 20
random 20
random 20
random 20
+ 30
+ 80
+ 30
+ 80
$1 5000
$1 7000
line 0.
line 0.
53.84
51.93
cycle~
cycle~
pfft~ hurrsaxpfft
pfft~ hurrsaxpfft
Volume Control
r starttbn
r resettbn
loadmess -70
live.gain~
delay 180000
stop
r shutoff
-30 20000
-70 0
-70 500
line 0.
-inf dB

Movement 6

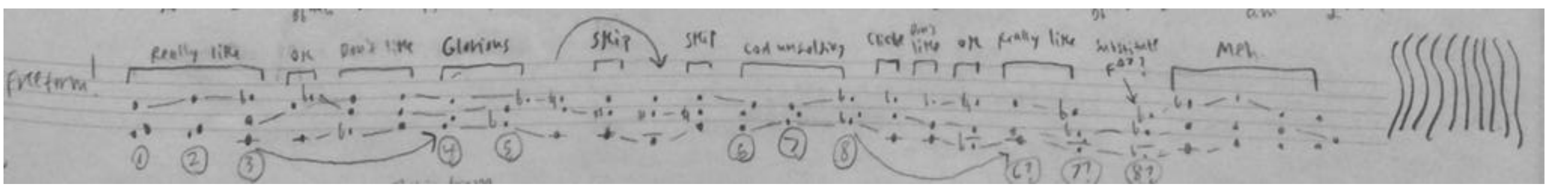
Despite its placement as the last movement of *Currents*, Movement 6 ("Occlusion") utilizes some of the first musical materials composed for the project. Concurrent with my early experiments sonifying live weather data with Max/MSP, I began thinking about translating the movement of weather patterns into notated music. Images of a geographical journey (weather fronts, lines, paths traversing from west to east) led me to use Lewin's transformational theory to construct harmonic progressions based on the movement of individual notes (Example 67).

Example 67

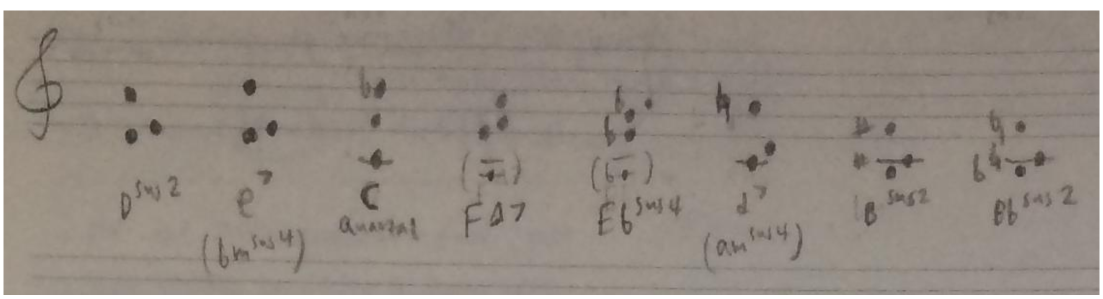


After several exercises that used motion based on a fixed number (i.e. all three notes in the chord must move up/down 8 semitones) or a countdown system (i.e. move all three notes up/down 8 semitones, then up/down 7, 6, etc), I began to freely compose my own paths starting generically on a D Major chord. This led to a lengthy chord progression of 25 connected harmonies (Example 68), which I truncated and rearranged into a progression of eight harmonies (Example 69). Each of the eight harmonies became tethered to a specific rhythm, instrument, and weather event (Example 70).

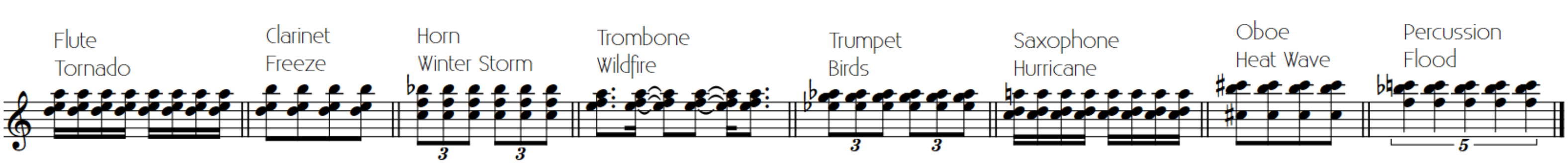
Example 68



Example 69



Example 70



The initial framework for *Currents* involved using this musical content as a prelude with subsequent development in follow up movements. At some point this idea was flipped, establishing this material as the end goal that other musical motives would fashion themselves into illuminating. Each of the solo events hints at the formation of this material, some as structural to the entire solo (horn, percussion), some as flickers of recognition in a beginning or ending motive (oboe, clarinet, sax, flute, trombone), some as a behind-the-scenes compositional process (the trumpet event). To further unify this idea, the members of "Group 2" in Movement 6 are given optional, improvisatory phrases based on musical gestures from their solo events to insert into their part.

The description below, which is taken from the program notes, serves as a brief overview of the "game" aspect of Movement 6:

> This final movement was inspired by a board game night with family friends. We played *Pandemic,*[44] a co-operative game where players worked together to defeat the board game itself. It was a difficult game to win, the board claiming victory much more often than the players. I thought of adapting this game to work in a musical context, where two unbalanced forces of players would compete to overtake each other in a game of chance.
>
> The rules of the game are as follows: the eight members of the octet are instructed to divide up into two groups (one smaller force of three, one larger force of five, with the percussion always in the second group). Dice are rolled to determine the starting point in the music, as well as the number of musical gestures the players have to finish to "win." Depending on the outcome of who overtakes who, there are two possible ways the music could end. If the smaller force (The inhabitants of a small town? The coastal residents of an island nation? The flora and fauna?) is lucky enough to overtake the larger force (The wildfire? The rising ocean? The shifting climate?), they will accelerate through their gestures and scatter off by the skin of their teeth, narrowly avoiding an apocalyptic fate. If the larger force overtakes the smaller force (the game is naturally

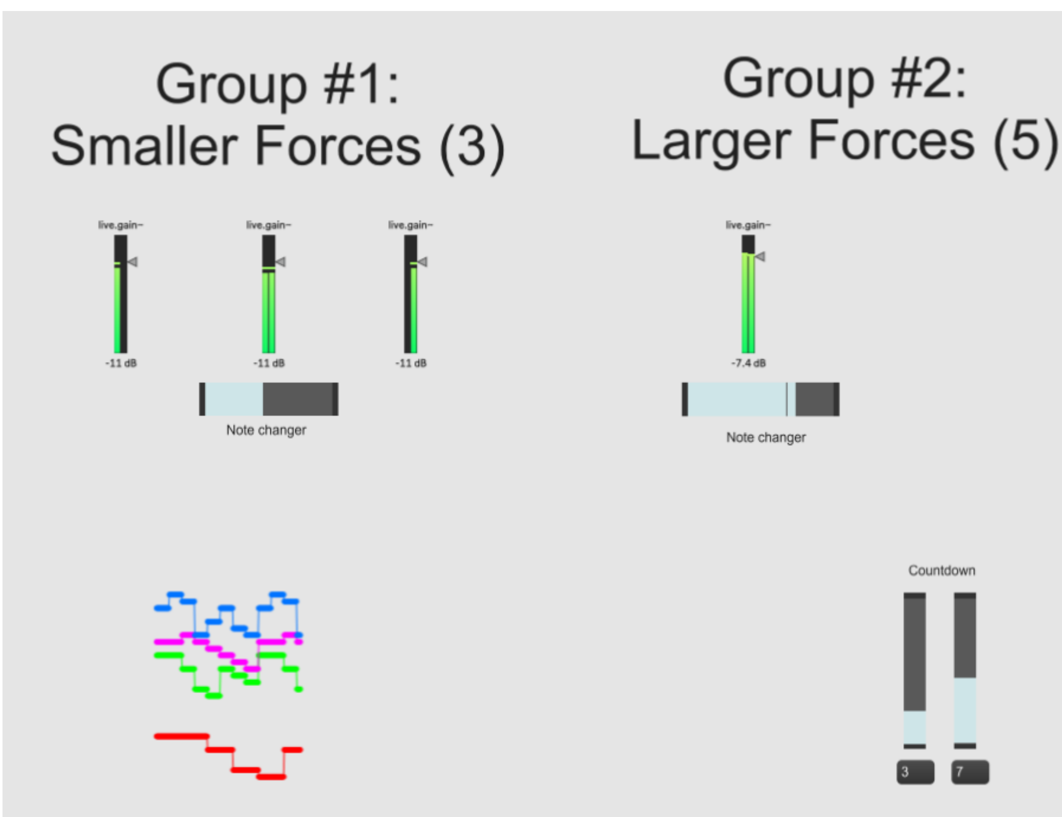
[44] The grave irony of typing this word in the midst of the coronavirus pandemic will always be haunting to me (3/22/20- ARJ)

stacked to let this occur more often), they will envelop everyone in an ominous (but oddly comforting?) blanket of sound, a reset to an empty new world.

This movement represents a macrocosmic event with all eight instruments depicting the unfolding of all eight events in real time, playing against each other across the entire surface of the Earth. It is easy to look at the forty years of data used throughout Currents as a constant, a fact of history, a given. This final movement is used to illustrate the uncertain, the unknown, the flap-of-a-butterfly's-wings kind of indeterminacy that comes with future meteorological events and larger shifts in the climate patterns on our planet.

A Max/MSP patch was created as a virtual simulation of this game (Example 71). A series of synthesizers (using several objects: "cycle~", "noise~", "metro", "adsr~") was created as the sound source, while a random number generator stands in as a virtual set of dice. Similar to the ones used in Movement 1, visual graphs tracking the pitch movement of the parts are implemented to further convey the theme of geographical journey and travel.

Example 71



CONCLUSIONS

In August of 2019, a memorial for the first Icelandic glacier to disappear from climate change (named “Okjokull” but nicknamed “Ok) was erected. Addressed with the title “A letter to the future,” the memorial reads as follows:

> Ok is the first Icelandic glacier to lose its status as a glacier. In the next 200 years all our glaciers are expected to follow the same path. This monument is to acknowledge that we know what is happening and what needs to be done. Only you know if we did it.[45]

Currents is a piece that exemplifies the sonification of weather data in various ways. It explores the possibilities of using computer software to create electronically improvised music, as well as the possibilities of using notated music to produce sound using live performers. It explores the specific method of sonification known as “remapping,” where other narratives (musical, as well as historical, cultural, political, and personal) are layered over the meanings found in the data. It uses geographical coordinates, hurricane wind speeds, and EF-Scale tornado ratings. It uses snow fall totals, vast timelines, and even vaster timescales. It uses temperature maps and JSON web data, live pressure readings and historical cost records, the voice of a Hurricane Katrina victim and the underwater recording of our crackling ocean. It even mines my own personal history with traumatic weather events. No matter how many ways this data is collected, parsed, scaled, sonified, and remapped, however, the narrative is always frighteningly consistent: we are in trouble.

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[45] Toby Luckhurst, “Iceland’s Okjokull Glacier Commemorated with Plaque,” *BBC News*, August 18, 2019, https://www.bbc.com/news/world-europe-49345912

Even in an age when 1 in 10,000 year events are occurring every other year, it is easy to brush off these phenomena as "just the weather." The data speaks differently, however. Collectively, the 258 weather events depicted in *Currents* have cost $1.75 trillion and have taken 13,249 lives. From 2010-2019 alone, there were 119 events that cost $802 billion and claimed 5,217 lives. And yet, just as the memorial to the Ok glacier warns us, we *know* this is happening, and perhaps it is more than *knowing* the data that can get us to *believe* that we are in trouble. Currents is a way of giving this data a more visceral narrative, keeping the conversation afloat about the urgency of climate change and the ominous shift in weather patterns on our planet. In the same vein as Jonathan Safran Foer, *Currents* is my attempt to translate weather data into a musical narrative, to translate *knowing* into *believing*.

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