<u>Soundtrack to the End of the World:</u>

Sonification of Climate Model Projections

Danice Ball

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1 Introduction:

"The saddest aspect of life right now is that science gathers knowledge much faster than society gathers wisdom."

Isaac Asimov

Numbers, equations, regressions. To measure the world. To understand it. To build things upon it. The measurements work quite well. The understanding, however, depends on much more than the measurements, and is often flawed. This results in externalized costs and flawed power structures, which end up reinforcing themselves as we build ever more complex measurement systems.

The world of climate data is uniquely complex. Exponential improvements in technology over the past decades have meant that measurements of the Earth's climate systems are now constant, monitoring the atmosphere's every move. The goal of much of this data collection is to then forecast the implications that the climate's current warming trends have on future warming trends and to predict the likelihood of future extreme weather events. Ultimately, this data collection strives to understand the various possible futures we have ahead of us. This is done through climate modeling systems.

"Watch out for intellect, because it knows so much it knows nothing and leaves you hanging upside down, mouthing knowledge as your heart falls out your mouth."

Anne Sexton

The problem is that there are many different climate modeling systems, and each of these systems produce astronomical amounts of data that stretch across time and space. Experts, let alone the general public, are not able to personally examine every scrap of this information. That task is given to computers. But computers aren't the ones who interpret data in order to make informed policy decisions or individual behavioral choices. Computers aren't the ones who have to internalize the fact that actual lives are at stake here: lives of people today and lives of people generations down the line. Computers aren't the ones who have to prioritize climate in their day-to-day lives. In order for data to be useful to society, it must be communicated by scientists to the general public. Because there is so much of it, picking out the notable trends becomes a necessity.

Science is incredibly important. But as a collective, humans do not understand, internalize, or respond to science. We respond to stories. When we do end up responding to science, it is almost always because the story behind the data was told in a convincing way.

Deciding which data to present and how to present it is referred to as framing. Framing allows a scientist to pick out and highlight the most important trends in a dataset in order to aid broader comprehension. This is usually done visually, through graphs. Laying out specifically chosen numbers over space allows people to communicate important changes and trends in these numbers over time.

This thesis will focus on an alternative type of dataset framing called sonification. Sonification is the conceptualization of data through sound. There are many different algorithms that can be used to sonify, each a different way of mapping notes into sound, typically with higher numbers corresponding to a higher pitch. Sonification first gained traction when entities such as NASA [1] began using it to help people understand the layout of galaxies. People have since used the technique to make better sense of income inequality on New York City subway lines [2] and to convey spatial data to people who are visually impaired [3] or less scientifically literate [4]. Various projects have also worked on sonifying climate data in particular, showing increasing temperatures and carbon dioxide levels over time through a more impactful medium.

"Music is psychology. And if the music does not penetrate the heart, the soul, the mind and the body, then you ain't gonna feel it . . . And if you don't feel it, you can't know it."

Peter Tosh

Music has always been an attempt to aggregate historical data, stories from the past, and transform it into a narrative to be interpreted by others. Classical composers drew inspiration from their predecessors, blues and jazz artists draw from the cultural strife and lost identity that is indicative of so much of Black history, a teen band tries to convey the complexities of bygone love. When these narratives hit just right, they become a cultural moment, a shifting of tectonic plates. They inspire listeners because of the personal connections drawn from the works. Because the music's interpretation of the past resonated with their own pasts, as well.

As numerical data becomes increasingly prevalent in society, we face the task of interpreting it, too. To help us make sense of the world. To help us make sense of ourselves. To help us make sense of potential pathways into the future.

Because sound impacts a more limbic part of the brain, it is often more memorable than visual stimulus [5]. Different types of music, as well as different moments within a given piece of music, correspond to different emotional appeals to an audience. When drafting a sonification, a series of artistic choices are made, such as onto which intervals and key signatures the numbers are mapped. These choices create different sonic experiences and therefore cause different feelings about the data at hand. Some choices could cause the data to be stored as a more potent memory than others, having a greater impact on listeners' future actions.

"Art never stopped a war and never got anybody a job. That was never its function. Art cannot change events. But it can change people. It can affect people so they are changed. . . because people are enriched, ennobled, encouraged, then they can act in a way that may affect the course of events. . . by the way they vote, by the way they behave, by the way they think."
Leonard Bernstein

Climate change necessitates radical changes in individual actions, psyches, and consumption habits. Vast infrastructural changes, such as transitioning the energy grid and establishing a more circular economy, are necessary in order to preserve the delicate balance of humanity and society with the natural world, as well as to prevent the increases in warming and catastrophe that climate models predict. Most of this must be orchestrated by political entities, who hold the power to alter societal structures. Political changes depend on popular support, which depends on the population truly understanding what is at stake. Thus, decarbonization efforts rely upon compelling data communications.

Today's world does not default to sustainability. In order to normalize low-carbon lifestyles, a critical mass of the population must actively care about pressuring a change in this default. This requires prioritizing sustainability over other things, such as convenience. If somebody has seen climate data trends framed and conveyed more impactfully, they could be more likely to bring this data and its implications to mind when voting and making everyday decisions.

This thesis hopes to help in laying a foundation and framework for climate model sonification. Because of its inherently artistic and emotionally-triggering properties, sonification has the potential to nudge people towards less carbon-intensive actions and policy choices on an individual level by making them step back and internalize data in a different way. This is especially powerful when that data deals with the future. Internalizing the numerical descriptions of our potential futures could help us gain agency over which one is realized. And in the case that we don't actually have any agency, it could help offer solace by providing a lens into the gravity of the unknown.

2 Scope:

Research Questions:

- How can the emotional capabilities of sound be leveraged into sonification algorithms with the intention of helping people better put large-scale, temporal, and numerical data into context?
- How do the intervals and range of notes that a dataset is mapped onto, as well as the temporal frequency of the data, affect the sonic experience?
- What are the potential applications of these data sonification algorithms?

Note: These sonifications are hosted at **https://daniceball.com/?page_id=55**

RCPs and NYC:

In order to communicate science, one must effectively and memorably convey dataset trends. Sonification is a very powerful way to do so. By altering the tonality of the sound, the number of notes included in the algorithm, and the frequency with which data is sampled, different trends can be highlighted. This thesis will compare sonifications of minor and major tonality and sonifications mapped over one versus six octaves. It will also explore sonifications of monthly versus yearly temperature data points.

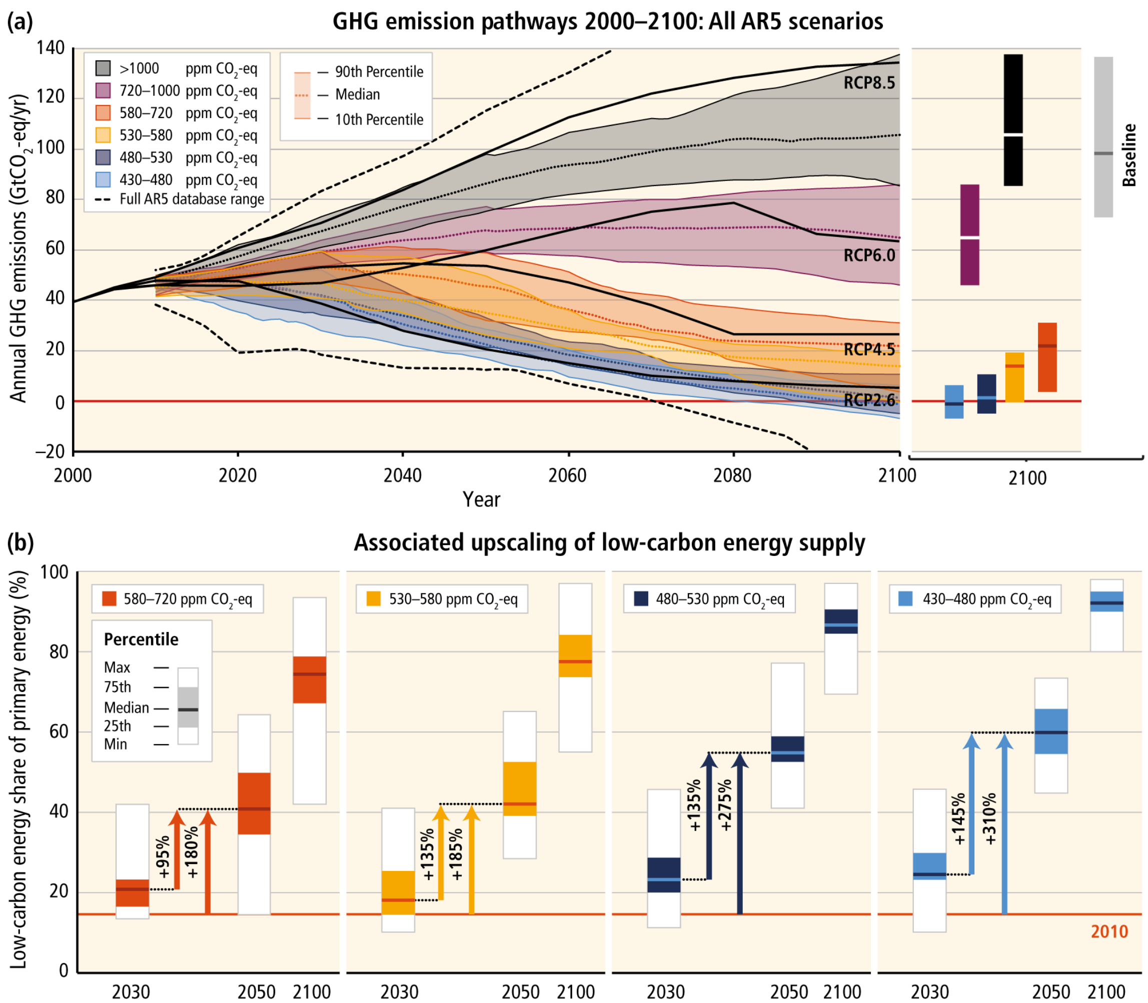
Two datasets, in particular, will be sonified. These are the 4.5 and 8.5 Representative Construction Pathways (RCPs) from The International Panel on Climate Change’s Fifth Assessment Report (IPCC5) [6] for New York City, NY, downscaled by the Community Climate System Model (CCSM) [7]. The sonic experience will be deconstructed using RCP 8.5. The final sonification for the project will then compare between the two datasets.

This thesis focuses on illustrating RCPs because of their prominence in international climate discussion. The IPCC5 Report [6] is one of the most widely-known and carefully researched conglomerations of climate data and policy goals. IPCC5 pinpointed four RCPs predicting the future levels of carbon dioxide, as well as other pollutants, in the atmosphere. These pathways do not delineate which human actions, exactly, would lead to each scenario, but rather how the Earth's radiative forcing processes would respond to different levels of emission. This is useful for setting policy targets and for understanding things like how natural buffer systems versus positive feedback loops will interact with different emissions scenarios.

The IPCC5's RCPs are constructed using CMIP5 models [8]. The Coupled Model Intercomparison Project - Phase 5 intends to model the interactions between carbon dioxide and other gas species with the Earth's hydrological systems in order to determine the resulting average global temperatures and precipitation levels [9]. Temperature rise is a result of radiative forcing, or change in energy flux of the atmosphere. Radiative forcing occurs as a response to emissions, and is followed by a change in temperature. This means that if emissions decrease, the warming that has already been set in motion will continue, but will taper off in the future.

As shown in Figure 1(a), RCP 2.6 is the most optimistic pathway. It assumes that CO2 emissions will peak around 2025 and then begin to decline. RCP 4.5 assumes that emissions peak mid-century and radiative forcing isn't stabilized until around 2100, while RCP 6.0 is even later. RCP 8.5 involves only increasing, though plateauing, CO2 emissions over time. The associated energy infrastructure transition metrics are also shown below, in Figure 1(b).

Figure 1(a) and (b): Emission projections for each RCP scenario, as included in the IPCC5 Report [10].



Climate models taking into account hydrology, geology, and biology downscale models like CMIP5 to specific geographic regions. There are many different versions of these models, all with slightly different predictions. The leading American climate modeling lab is located in Boulder, Colorado. Their model, the Community Climate System Model (CCSM) [7], a subset of the Community Earth System Model, runs four simultaneous climate models of atmosphere, ocean, land surface, and sea ice with a coupler component in order to produce forecasts of temperature, precipitation, and other variables for any zip-code on Earth according to RCPs 4.5 and 8.5.

New York City was chosen as the focus of this project because of personal connection to New York and first-hand experience of the effects of climate change on New York weather patterns.

Predictably, RCP 4.5 results in less dramatic temperature increases in the region than RCP 8.5. Higher urban temperatures in the summer months lead to greater energy demand, mortality, and exacerbation of the Urban Heat Island effect. This all feeds a vicious cycle of even higher temperatures [11]. The New York City Panel on Climate Change [12] recognizes these increasing extreme temperatures, as well as increasing precipitation and sea level rise, as being major threats that must be built into future resiliency plans for the city.

By investing in natural carbon sinks, expanding electric vehicles and public transportation, transitioning to a more renewable energy grid, and offsetting irreducible emissions, New York plans to be carbon neutral by 2050 [13]. The New York Mayor's Office of Sustainability found in a study that this target was quite achievable, technology-wise [14]. However, these types of changes and transitions require the buy-in of the population that is expected to change and transition, as well as the buy-in of their leadership. People who better understand the projections at hand will hopefully be more likely to buy-in to these necessary transitions and prioritize climate in their voting and personal habits. Sonic experience could defamiliarize data in a way that could help with this understanding.

Before these sonifications are presented and discussed, the literature revolving around the effect of music on the emotions and the effect of emotions on the psychology of decision-making is explored and the process of sonification explained. To conclude, this report discusses possible implications of this project in climate-related and other fields.

3 Literature Review:

Music and Emotion:

The effect of music on the emotions has long been theorized. While cognitivists focus on art and music as ways for someone to *express* their own emotions, the emotivist school of thought holds that these types of expression can also be used to *elicit* certain emotions in an audience [15].

Studies such as that done by Krumhansl [16] find low correlation between type of music and physiological effect on the brain and body. However, other studies do find that music produces emotions. These studies measure emotions using subjective mood-scaling techniques, rather than physiological measurements [15]. Correlations between the emotion a composer was hoping to induce and the emotion of the listener are found in studies such as that of Juslin [17], who evaluated level of happiness in listeners after listening to “happy” versus “sad” music using a self-report method measuring subjective experience.

It is generally agreed upon that songs in a minor key come across as sadder than those in a major key. There are various theories as to why this is the case. One is that Western culture, in particular, has reinforced a cultural assumption and expectation of this sadness over time [18]. Minor tonalities are also structurally different from major tonalities. The interval of the third is always flat in a minor key, with the sixth and seventh intervals sometimes flat as well. This produces a more uncertain and variable form that registers as lower than expected. This parallels human communication, where lower tones often indicate sadness [19]. Sonifications mapping data points into a major scale could, therefore, produce a happier feeling in an audience than the same data points mapped onto the notes of a minor scale.

Playing dissonance and harmony off of one another is a part of every musical composition. As described by Adam Neely [20], patterns of discord and resolution signal to a listener discomfort and chaos and then comfort and contentedness. The intentional creation of an uncomfortable sound is often used to pique the interest and attention of an audience, similar to the literary device of cacophony, used to communicate discomfort [21]. Too much of this discomfort, however, could be overwhelming to a listener. In this project, cacophony is increased by mapping the same data over a larger range of notes, as well as (separately) by mapping monthly data, rather than yearly.

Of course, there are many other factors at play in the interpretation of a certain strand of sound or music. The affective state that is induced in a listener largely depends on that individual's previous experiences and associations with similar sounds. Different areas of the brain work together to produce these associations and emotions [22].

Emotional Frames and Environmental Decision-Making[1]:

The associations and emotions that are active at a given time dictate the structure of logic that is applied to a given problem and the pros and cons that are emphasized in a person's reasoning. The field of behavioral psychology in decision-making and judgment deals specifically with this wide variety of potential frames and how they influence individual and group behavior.

Frames that activate intrinsic motivation are theorized to have a larger effect on actions than those activating external motivation [23]. Environmental framing mechanisms emphasize information about the positive effects an action can have on the environment. This makes a person feel good intrinsically. Economic frames, in contrast, highlight the money saved by taking an action. This is an extrinsic motivator. Asensio and Delmas [24] found in an environmental decision-making study that households use 8% less energy when they are prompted with environmental framing mechanisms than when the same action is pitched as being slightly more economically beneficial. Schwartz [23] and Steinhorst et al [25] found something similar, concluding that people are less likely to enroll in energy conservation programs when the

[1] I've spent the last two years working at the Princeton Behavioral Science for Policy Lab under Professor Elke Weber. Many of the ideas discussed in this paper spring from those discussions and that research.

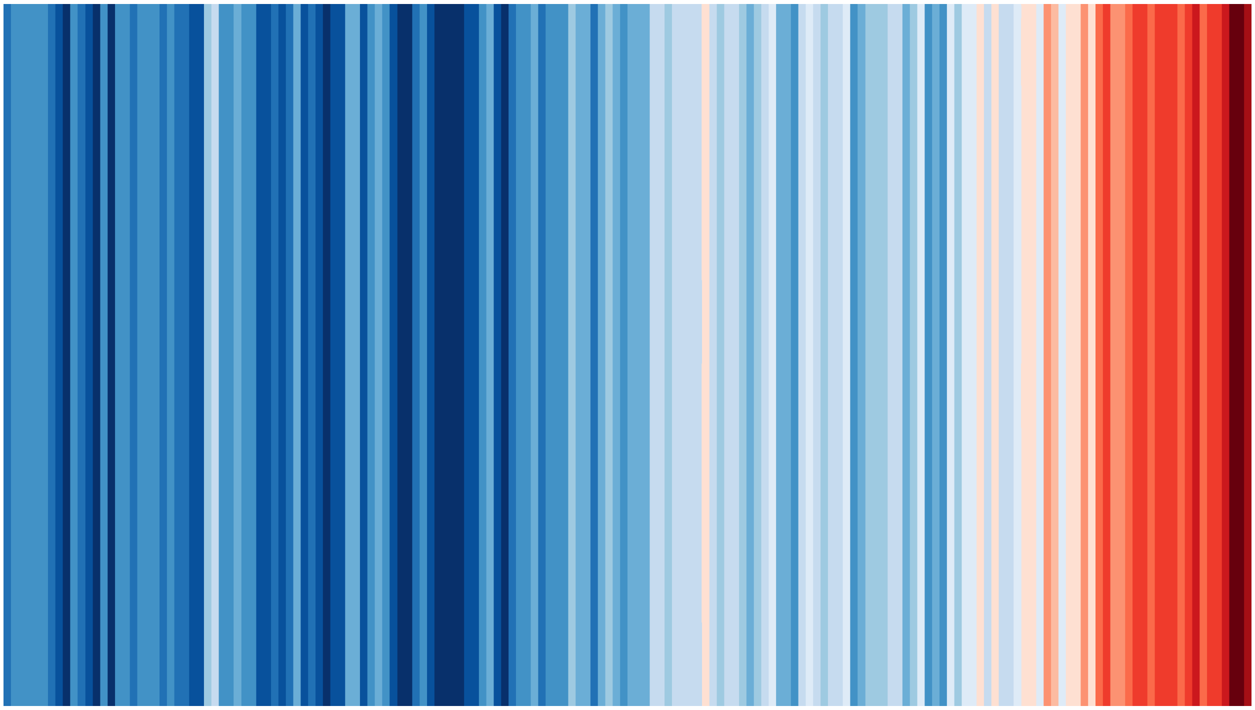
benefits of the program are framed according to financial gains, rather than environmental benefit. Bolderdijk et al [26] also find this greater potency of environmental, rather than financial, framings, saying that these findings could be due to the fact that “many people would rather feel green than greedy.”

Popa and Salanta [27] analyze the interplay between this intrinsic motivation and a person’s emotions, concluding that emotions can heighten motivation, but that this also goes the opposite direction, with a person’s level of motivation influencing the emotions that they feel in the first place [27]. Regardless, activating internal motivation through appeals to emotion can be a powerful way to nudge people towards taking certain actions, especially with regards to environmental decision-making. Various forms of climate art experiment with heightening emotions to induce action. In order to do this, they must achieve the necessary balance between optimism and call-to-action. If the situation isn’t conveyed as dire enough, people will not be motivated to change anything about their lives. On the flip side, despondency does not lead to action, either.

Framing Data Through Visualization and Sonification:

The challenge, then, lies in communicating the trends of a dataset without overwhelming the viewer/listener. One way to go about this is by showcasing data in unconventional ways. For climate data, one of the most famous examples of this is displayed in Figure 2, where a color scale is employed to illustrate the minute yet potent difference in temperature that will be caused by anthropogenic emissions [28]. When data is translated into unexpected mediums such as color, it is defamiliarized in a way that can pique attention. Sonification does something very similar.

Figure 2: Warming Stripes. 1.35 ºC change in global temperatures from 1850-2017, shown through changes in color hue [28].



Sonification projects use coding techniques to turn large amounts of data into sound, with variations between the notes acting as the variations in hue do above. Climate sonifications do this with climate data and models. Hua Zhang [29], for example, sonified increasing historical temperatures in Montana by overlaying flute yearly trends, piano monthly trends, and harp residuals (i.e. temperature changes corresponding to even shorter amounts of time). While the residuals changed frequently and unpredictably and the monthly values changed seasonally, the flute got higher as time went on, allowing one to hear the climate gradually changing. KQUED [30] has produced a similar sonification consisting of a synthesized note getting higher as years approach the present. The UCAR museum in Boulder, Colorado (the same organization that produced the CCSM4 downscaled data used for this project), hosts a "Sounding Climate" exhibit [31] in which a person can choose a location on the globe and then listen to both past temperatures and future projections in C Major.

There are also musical projects that seek to convey climate change through more hands-on composition efforts. Jamie Perera [5] is a prominent climate musician. His most well-known piece, “Anthropocene in C,” is meant to be performed live. It was written with the intention of helping people come to terms with their experiences of climate grief, which often manifests as a guilt for “betraying” future generations or a mourning for the loss of our current natural beauty. The idea is that music can help define fleeting emotions, nudging us into action, especially when that music portrays the numerical data that illustrates the changes that cause the emotion in the first place.

Perera’s music is based firmly on numerical data, and thus is definably sonification. This is not the case for “The Lost Seasons” [32], an interpretation of Vivaldi’s “The Four Seasons” in a changed climate, or the Climate Symphony [33], a project completed to convey the sense of loss as climate change progresses. These works are related to Perera’s work in concept, but do not use actual data. They are purely composed based on feeling. They are, however, similar to climate data sonification efforts in that they are trying to convey a sense of urgency in the hope that an audience will emerge with a changed view on climate-related issues and decisions.

Taken together, these projects showcase some of the current efforts underway to sonify climate data. These sonifications potentially have the ability to heighten the emotions of an audience, increasing intrinsic motivation, which in turn can affect environmental decision-making. This thesis intends to add to the growing field of climate data sonification by demonstrating the choices that must be made in the sonification process, thus providing a foundation and springboard for future sonification efforts.

4 Methodology and Data Sources:

Sonification, Deconstructed:

Below are the steps involved in creating a sonification. Figures 3 and 4 detail this process.

1. Choose the rate at which the data is sampled. More frequent data points (i.e. monthly rather than yearly) will result in more detailed information transmission and likely sound more chaotic. Code can resample the given data into new time periods. For example, to convert monthly data into yearly, the data is condensed and transformed into the average of every twelve monthly data points.
2. Determine the minimum and maximum of the dataset.
3. Set the key signature for the sonification (usually C Major).
4. Choose the tonality of the sonification. Minor tones will likely sound more uneasy. By specifying C Minor, the E and A of the scale for the algorithm become flat.
5. Choose the lowest and highest note. A wider range will sometimes overwhelm, but will encode more detail. These notes correspond with the minimum and maximum data points.
6. Set the tempo for the sonification.
7. Run the code. The intermediary notes are matched to whichever location between the high and low notes best corresponds to their relative proximity to the minimum and maximum. For example, if data were mapped over an octave, and the first data point was 7/8 of the maximum, it would be mapped to the note coming directly before the top of the octave.
8. Combine the resulting audio file with other sonic and visual material.

Figure 3 illustrates sonification on the scale of notes, rather than the usual octaves. The blue grouping splits the data into two notes, with values above the median getting played on the higher. The red grouping splits over eight, allowing more distinction between data points. Points 1 and 2, when mapped over eight notes, would be two notes apart, with 1 on C and 2 on E or E flat. When mapped over two notes, however, both end up mapped to the same note, G.

Figure 4 shows numerical data twice plotted over a musical staff. The blue plot is stretched out over less notes vertically (one octave rather than three), diminishing the sonic variation in the numerical differences. The dots on the right hand side delineate the E and A flats.

Figure 3: Sonification over two versus eight piano keys (Danice Ball, 2022)

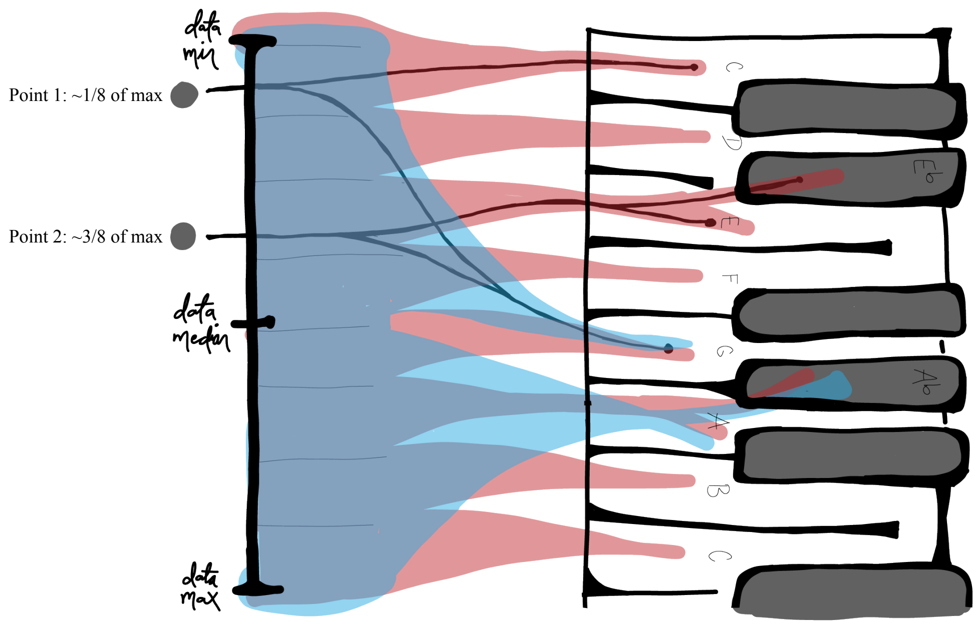
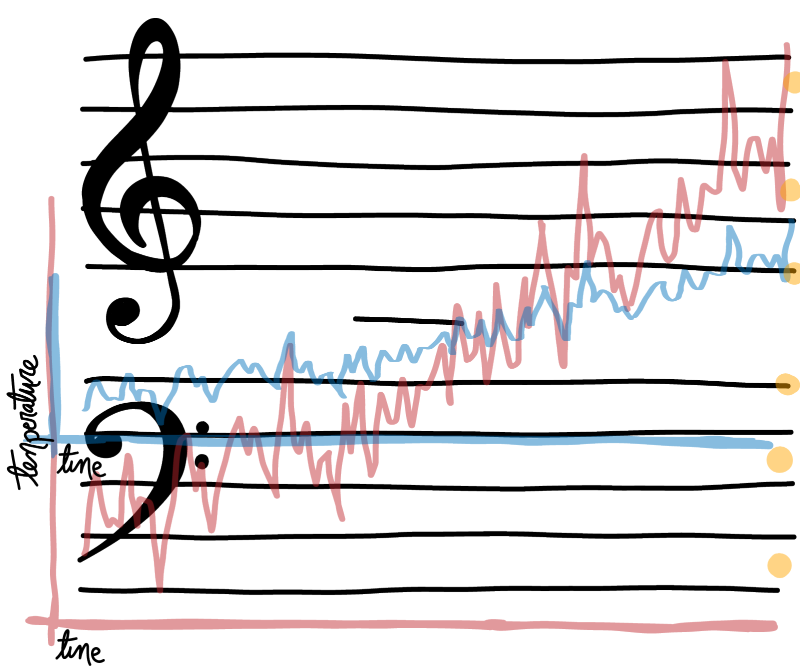


Figure 4: Mapping of data over one versus three octaves of a musical staff (Danice Ball, 2022)



Data and Code Sources:

This project draws from the Multivariate Adaptive Constructed Analogs (MACA) dataset [34], which uses CMIP5 RCPs 4.5 and 8.5 [8] to produce CSV files of historical and future temperature values for specific latitude and longitudes, downscaled by various global models. The data used for this project was downscaled by the CCSM4 [7] and consists of maximum monthly temperatures for the NYC region.

Code for this project was created drawing from the MidiTime sonification API [35] created by Michael Corey. MidiTime's commands convert time-series data into pitch, velocity, and duration values. The commands can be combined in different ways to specify how the code should come to these values.

Methodology:

The code created for this project is structured so that a user first specifies the time intervals at which a CSV file should be sampled. It then prompts as to what key signature and how many octaves the data should be translated. The note that corresponds to each data point is found by taking the minimum and maximum temperatures of RCP 8.5 and assigning them to the lowest and highest specified notes. Each datapoint, then, is assigned to whichever note on the specified range is located between the lowest and highest note in the same proportionality as the datapoint is located between the RCP 8.5 monthly or yearly minimum and maximum values.

For this project, the tempo is held constant at 120 bpm (unless otherwise noted), and the key signature is kept at C, major and minor.

There are three important things to note about the minimums and maximums in this project:

- When dealing with yearly data, the code resamples the monthly dataset by taking the average of every twelve data points. For these sonifications, the minimum and maximum values are different from the monthly sonifications, as there is a smaller range of data points.

- The minimum and maximum values always come from RCP 8.5, even when sonifying RCP 4.5. This is to aid comparison between the two datasets.
- As the data itself is made up of monthly maximum temperature values for the NYC region, the "minimum" value as referred to here is the minimum of these maximums.

The previous description creates a sonification that represents one line of data as sound. These sonifications were then put into iMovie. This software allowed the sonifications to be layered on top of one another and combined with their graphical representations. The tempo of some of the final pieces were also further altered.

5 Sonification:

The sonifications discussed are hosted at:

https://daniceball.com/?page_id=55

They sonify the data shown in Figures 5, 6, 7, and 8.

Figure 5: RCP 4.5 Monthly Maximum Temperatures

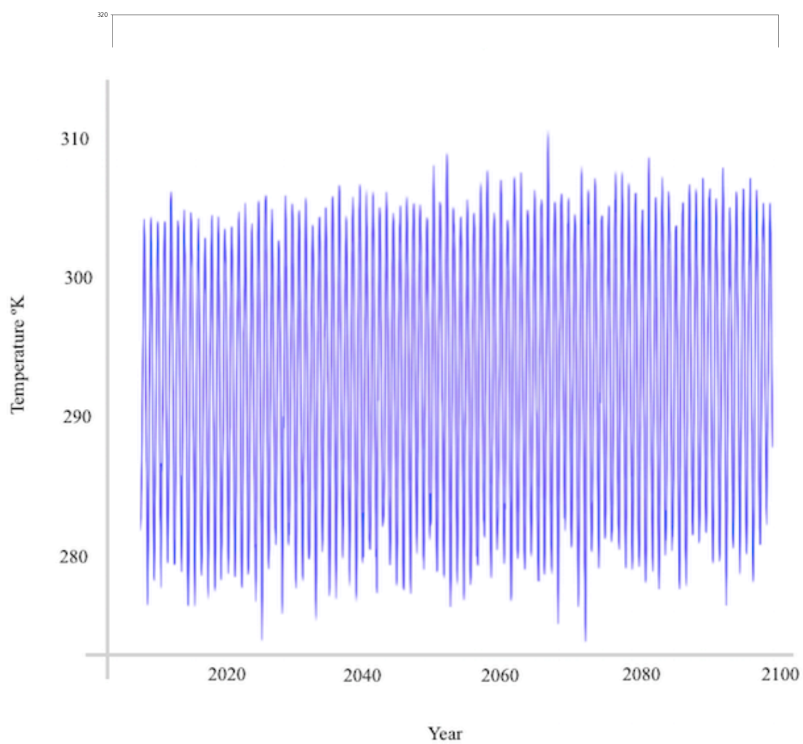


Figure 6: RCP 8.5 Monthly Maximum Temperatures

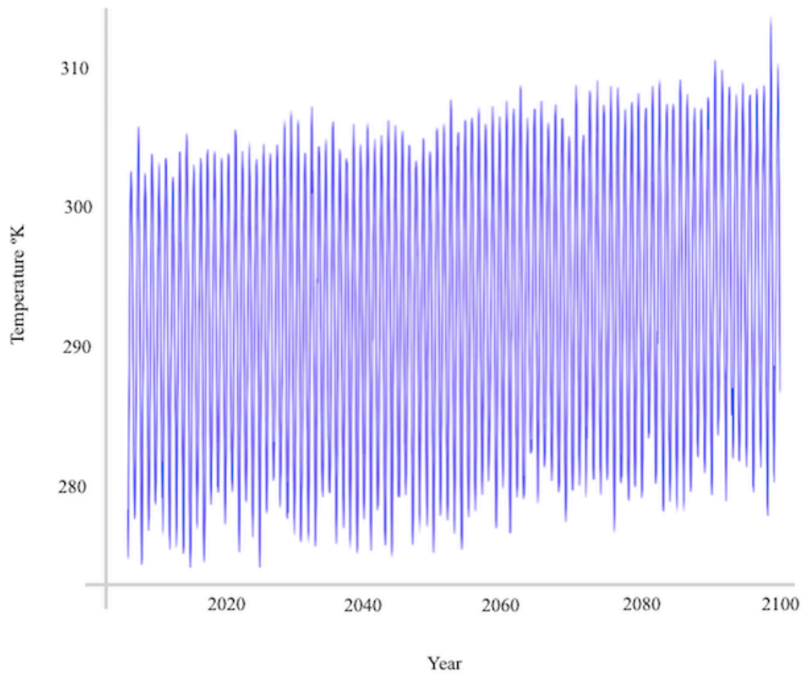


Figure 7: RCP 4.5 Yearly Maximum Temperatures

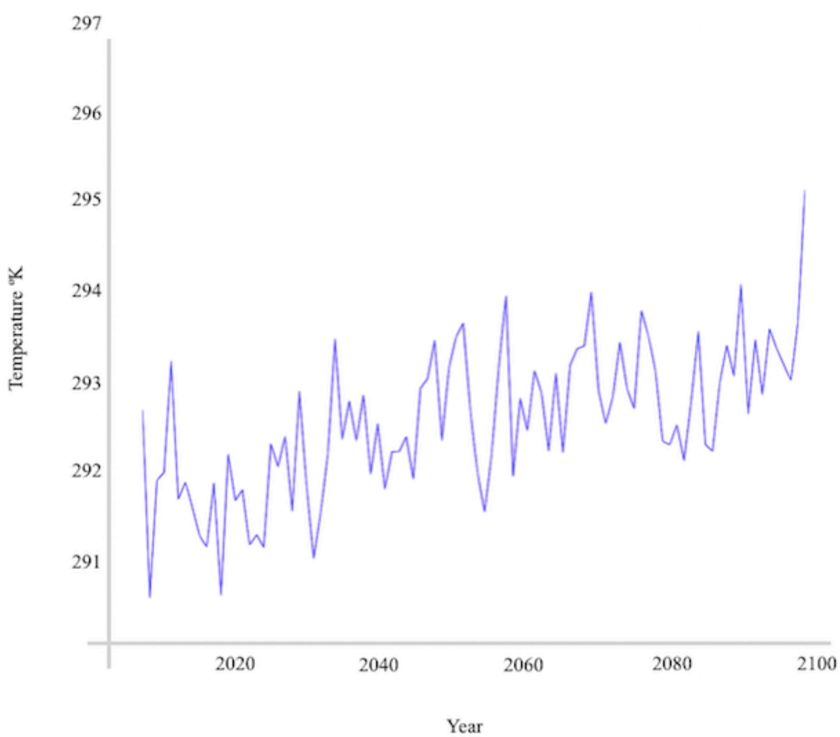
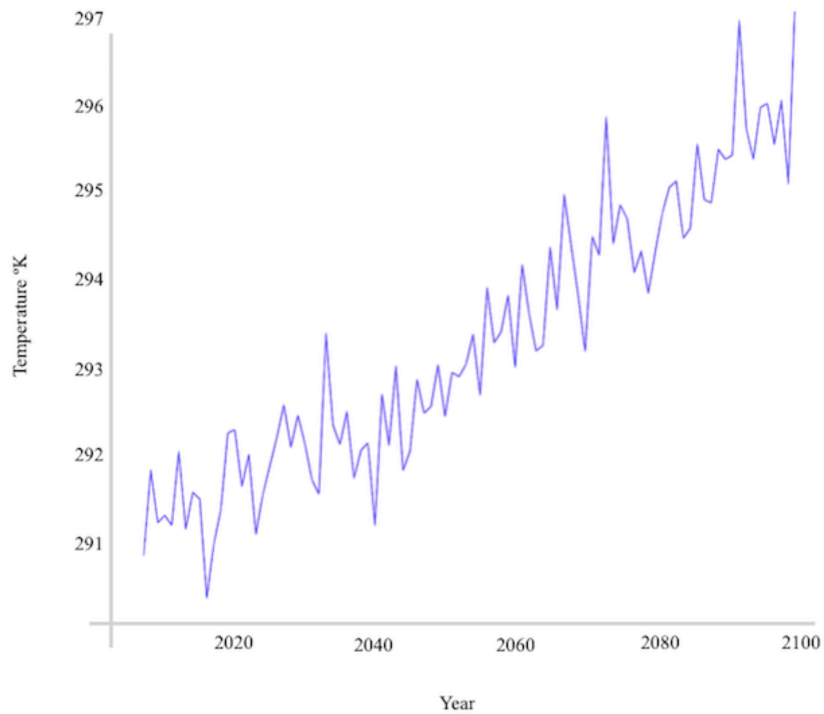


Figure 8: RCP 8.5 Yearly Maximum Temperatures



Understanding the Sonic Experience:

This project deconstructs three aspects of the sonic experience: monthly versus yearly data points, minor versus major tonalities, and mapping data over one versus six octaves. To conclude, the monthly and yearly data are combined with one another to create a holistic composition of each dataset. These two compositions can then be compared to one another.

I: Data Sampling Frequency (https://daniceball.com/?page_id=382):

Sampling data at different time intervals causes long-term trends to sound different. In the case of temperature data, monthly data is made up of rapid seasonal fluctuation. For every year that passes, the temperatures have to include winter, as well as summer, values. This often causes the monthly data to sound much more confusing than the yearly data, which is composed of the average of every twelve monthly values. Averaging takes away a listener's ability to fully internalize the annual patterns of the data, but at the same time should make it easier to recognize the general trend of increasing yearly temperature.

This section compares sonifications of Figures 2 and 4. The yearly piece in this section was sped up to three times its 120 bpm speed to better illustrate this potential increase in trend recognition.

II: Tonality (https://daniceball.com/?page_id=319):

Especially in the Western world, a major tonality signifies comfort and positivity more so than a minor tonality. The minor mapping uses Eb and Ab rather than E and A. Changing those notes by that half step has a noticeable effect on the feel of the sound. Sonifications mapped to minor tonalities, stressing the minor 3rd, have the potential to make an audience feel more uncomfortable than sonifications using the more "beautiful" major 3rd. This is because more discordant intervals are being used as the building blocks of the sonification, creating a more agitating sound.

This section compares two sonifications of Figure 4. The pieces in this section were sped up to three times their 120 bpm speed.

III: Octave Mapping (https://daniceball.com/?page_id=436):

A wider range between the lowest and highest notes in an algorithm allows for more nuance in a sonification (less "rounding" up or down to surrounding notes). For example, mapping to a range of eight notes means that the highest 1/8 of the dataset is mapped to the highest note. Since the temperature is rising, the highest note is played more and more frequently as the sonification goes on. In contrast, when this data is mapped over six octaves, or 43 notes, only the top 1/43rd of the data is mapped to the highest note, and the highest note is only played once or twice. With the set mapped over more octaves, there are more notes at play. This allows for a greater level of detail to be communicated through sound, but also is sometimes overwhelming to a listener.

This section compares two sonifications of Figure 2.

Finale - Comparing RCPs 4.5 and 8.5 (https://daniceball.com/?page_id=515):

It is difficult to compare between datasets of temperature predictions because changes in the atmosphere's temperature are much more minute than the effects they induce. The maximum temperature between today and 2100 for RCP 8.5 is only 4º higher than that of RCP 4.5. This is one of the reasons why people find it so hard to internalize the effect that we are having on the natural world.

In order to frame temperature data in a compelling way, trends must shine out of the greater chaos. The final compositions of this project consist of a backtrack of each RCP's monthly temperature data sonified over one octave. The yearly data for each RCP sonified over six octaves is then overlaid as a sort of melody. The graphical equivalents of these pieces are shown in Figures 9 and 10.

Figure 9: RCP 4.5 Monthly Maximums (with Yearly Average Maximums Overlaid)

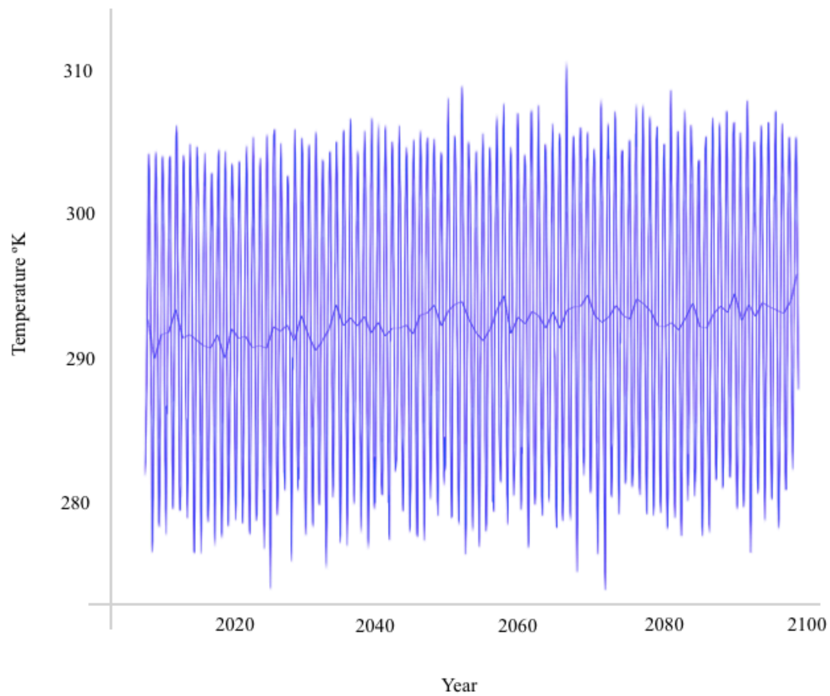
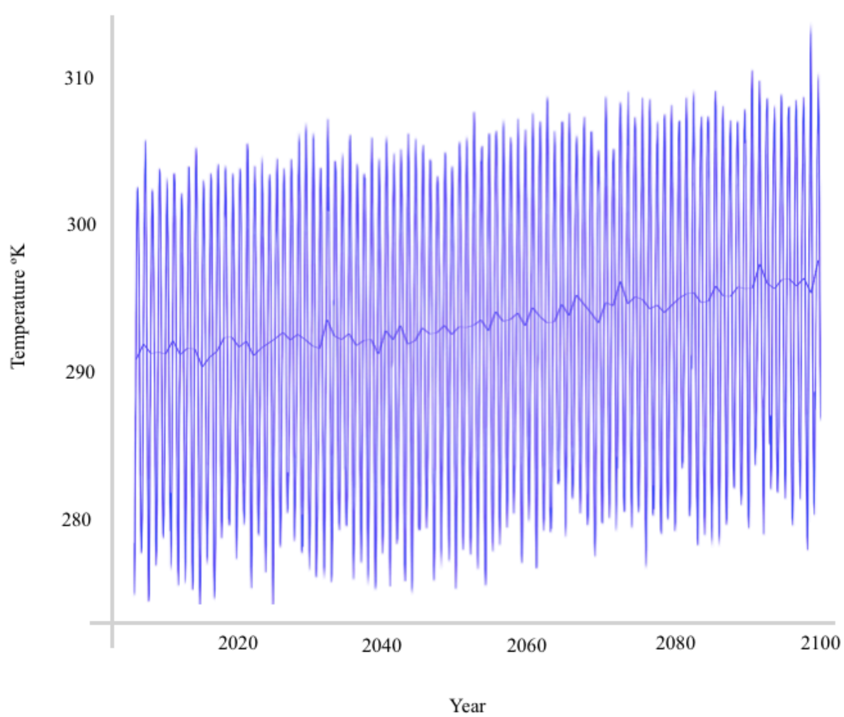


Figure 10: RCP 8.5 Monthly Maximums (with Yearly Average Maximums Overlaid)



Comparing a sonification of the 4.5 pathway with that of the 8.5 pathway, both sonified according to the same algorithm, hopefully sparks a different understanding of the differences between the two datasets, and the much more drastic rise of the latter. This more drastic rise should induce a greater feeling of anxiety in a listener. The knowledge that this anxiety corresponds to a possible future is powerful.

Combining monthly with yearly data allows a listener to better internalize the complexity of the story the data is telling; the backtrack of the seasonal variation behind the gradual rise in temperature.

The visual media included in the background of these final compositions consists of my personal photography and artwork, revolving around themes of urban landscapes, climate change, and futurism. The visual media included in the RCP 8.5 video was curated to invoke a higher feeling of dystopia in order to work in tandem with the steeper increase in pitch.

6 Further Research:

This project touches only on a very specific set of data. It could be expanded and improved upon in many ways. Firstly, and perhaps most obviously, the idea of sonification of climate issues can be extended to other climate data, such as historical temperature and precipitation records and other climate models. As of this writing (2022), the IPCC just released the 6th Climate Change Assessment Report [36], which slightly amends the RPCs, presenting great potential for comparison.

The methods described here could also extend to any subject matter dealing with numbers and time. The possibilities seem especially potent in the fields of African American Studies[2], immigration reform, and capital flow analysis/reform, all of which demand that we look to the past in order to be the architects of our own collective futures. Datasets could be layered upon one another, sonified as its derivatives to illustrate changing rates of change, combined with other auditory and visual materials, and communicated through chord resolution techniques. They could be widely distributed electronically and performed live. This project is meant to serve as a foundation and framework as sonification is expanded into more meaningful and artistic works. The possibilities are truly endless.

[2] One of the biggest breakthroughs in the writing of this thesis came from my Radical Composition class with Professor Tina Campt, which compared frequencies of visual, sonic, and literary works in the context of Blackness.

7 Conclusion:

"We are responsible for the world in which we find ourselves, if only because we are the only sentient force that can change it."
James Baldwin

Humans are crazy wacky wild. Society is a beautiful glitch of consciousness and progression of collective understanding. It is in our best interest to maximize the exquisite and powerful interactions within humanity and between humanity and the natural world, if only for the purpose of self-preservation.

As far as climate goes, this is all a game of a few degrees. Four degrees is the difference between the maximum temperatures of RCP 4.5 and RCP 8.5. As individuals, we do not perceive four degrees' difference as we step outside. But four degrees, compounded into atmospheric feedback loops over many years, results in a drastically different set of ecosystems and level of livability for the future world.

We do have some control over how many of these degrees of warming actually come to fruition. It is our action, after all, that is causing the warming in the first place. But decreasing emissions to the necessary level is a matter of collective action. One person's choices only matter when compounded across the population. The easiest way to compound these choices is by changing the choice architecture presented to this population. But in order to change the choice architecture, that very population has to want to change it. The American economy and consumption habits are a direct reflection of what the people truly care about. Not what they portend to care about, in abstract, but what they actually prioritize when going about daily life.

"Art is not a pleasure, a solace, or an amusement. Art is a great matter. Art is an organ of human life, transmitting man's reasonable perception into feeling."

Leo Tolstoy

A person's priorities only change when they fully realize a new piece of information. Collection of information requires absurd amounts of coordination. Science does this quite well. However, effective dissemination of information, getting people to realize it, requires something more subtle. It requires one to effectively wield the tools of communication and perfect the art of the minutia. If it was just about getting people to look at data, globalized communications would've solved all of our problems. We would live in a utopia. But it's about more than that.

People oscillate on a spectrum between rationality and feeling. Our decisions reflect the information and subtext that we've internalized as of the moment that decision was made. This means that we don't push back against the status quo because we've merely seen the numbers. We push back when we care. When a story strikes the right chord of perception. When something becomes personal enough to go against the grain.

And art is a tool of personalization. Art allows us to remind each other that there are other eyes viewing, brains thinking, hearts beating, and that these eyes and brains and hearts might have a different perspective than our own. Simultaneously, art works against desensitization. Shoving painful concepts in faces numbs viewers. Art, however, takes a circuitous route that encourages the internalization of these concepts. People, then, hopefully look more closely at the world and its problems and have a greater motivation to find and move towards solutions.

I'm not one to say whether art can actually motivate the shift in collective mindset that is required to create a truly sustainable society. But I will say that I believe to my core that if there were such a thing that could do so, art would be it.

Music serves the purpose of storytelling. Of taking scraps of our individual and collective pasts and weaving them into a narrative. Of making sense of multitudes of moments by leveraging the minutia of the sonic experience. Society is becoming increasingly dependent on and saturated by technology, numbers, and vast amounts of data. These things seem daunting in the same way that cultural histories and personal experiences always have. And music can make sense of them, too.

This has been my attempt to showcase the potential of sonification. Sonification allows feeling and numbers and time to be communicated in a very powerful way. It allows the essence of numerical trends to be translated into sonic equivalents in order to better tell the story behind the data. My hope is that these efforts will be expanded on by myself and others in years to come.

From the bottom of my heart, thank you for looking at this work. Please think on it and get back to me. I wish you all the best.

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Dani

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