**STAT679 - Group 2 (Samuel Merten, Osama Kheshaifaty, Yu Luan, Cameron Jones)**
**Project Milestone 3**
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**Public Code Link:** https://github.com/cjones46/992GroupProject

## 1. Introduction

In this project, our team visualizes the spatiotemporal relationship between bird migration and temperature patterns in the continental United States over 2000-2023 for the American Goldfinch and Song Sparrow, two of the most common migratory birds in the United States. We have developed a comprehensive interactive interface which enables the user to explore numerous possible queries about the relationship between spatiotemporal bird migration and temperature, at the level of months and states.

These queries include visualizing bird migration and temperature patterns over a specific time period, understanding how those patterns have changed over time, and how they relate to each other. Our hypothetical client could be the Department of Ornithology or Climate Studies at a university or government agency interested in understanding how climate change affects bird migration, both in the short and long term.

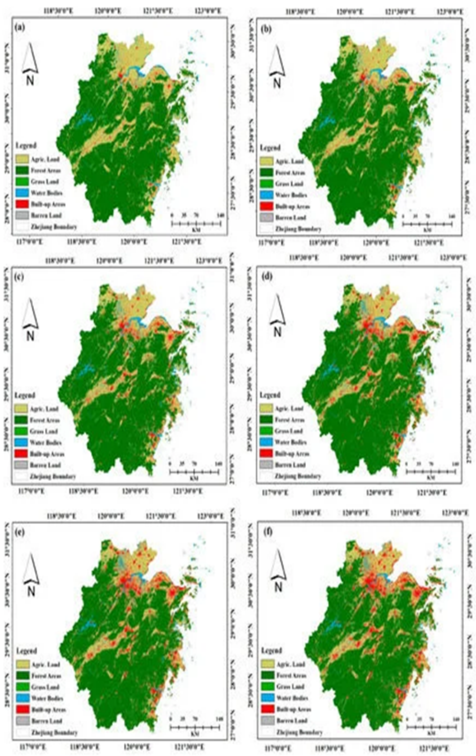
As we will see in the following section, spatiotemporal movement and temperature visualizations individually are rich with examples in their respective literature. However, our project makes the novel contribution of combining the two with the express purpose of exploring the relationship between bird migration patterns and climate change.

## 2. Literature Review

Conveying the distribution of a continuous or categorical variable over discrete spatial units and temporally is a common task, to which Chen, Wang, & Chen (2015)[1] present a static solution. Seen in Figure 1 on the next page, the authors encode a variable of interest spatially with color, overlaying it upon a recognizable map of geographic features (in this case, a map of China's Zhejiang Province). We take inspiration from this approach to spatial visualization, as we encode bird population and temperature data spatially with color, overlaid upon a map of the continuous United States. Since relative comparison of a continuous variable is facilitated intuitively by color (while absolute evaluation may not be, it is not a focus of our project), we felt comfortable extending their use of color from a categorical to a continuous variable.

However, these authors were likely limited to static visualizations, which necessitated their reasonable (but suboptimal) choice to provide six static snapshots. The burden on the viewer is increased here; as it is hard to track a specific spot between each snapshot, especially those which are not immediately next to each other. Furthermore, while the general trend is visible by comparing the first and last panel (difficult itself given their visual distance), it is hard to tell from the intermediate panels if the trend is linear or something else.. We improve upon this by allowing the user to specify a month and year to visualize; allowing information for one point to stay in the same spot in the screen as time changes, facilitating understanding of the rate of change. Furthermore, there is no timestamp visually associated with each snapshot, just letters which refer to a key provided in the text. We improved upon that in our project with dynamic titles of graphs which update based on user queries.

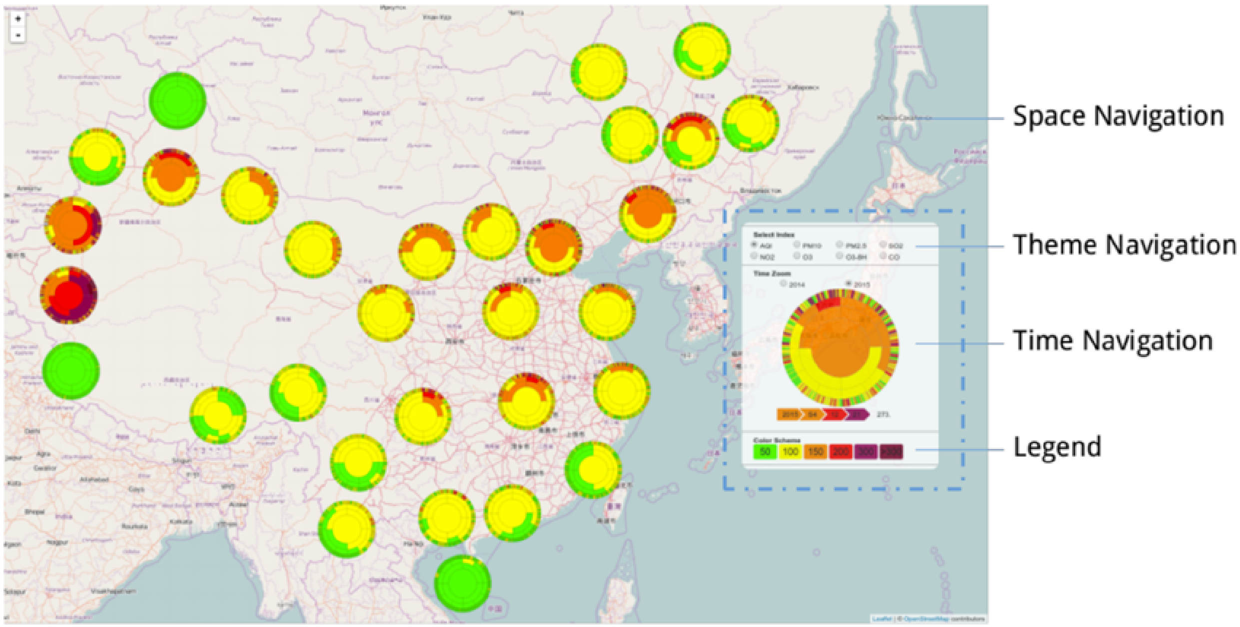
**Figure 1: Chen, Wang & Chen (2015).**



***The authors encode the spatial distribution with a natural color scale, and the temporal distribution with six selected static snapshots. In our project, we take inspiration from this visual by encoding temperature spatially with an intuitive color scale, but extend their static temporal encoding to an interactive one.***

Chen, Wang, & Chen above plot color along a grid so granular it appears completely continuous. This would pose two challenges to our project. The first is data availability and processing. Finding temperature data along a fine grid both spatially over the continental US and temporally over the last 22 years is difficult, let alone processing it quickly to interactively plot it. The second is that a continuous map may not align with the goals of our project; certainly, the viewer does not care about daily fluctuations, and could reasonably care about comparing states instead of individual spots. We take inspiration from Lu, Ai, Zhang & He (2017)[1] in Figure 2 below; they select major Chinese cities as their discrete units of interest, understanding the level of granularity the reader is interested in - we summarize to the state level in this fashion.

**Figure 2: Lu, Ai, Zhang & He (2017)**




***The authors discretize space into a visually manageable number of units of interest by focusing on major Chinese cities. We take inspiration from this in displaying trends at the state level, rather than a finer spatial grid.***

## 3. Designs

We chose the Design Studio modality for our project, designing an interactive interface to explore spatiotemporal bird migration and temperature patterns.

### 3.1 Interface

The interface is implemented with Shiny, with individual visualizations through ggplot2. The app consists of four tabs: 'Bird Species Summary', 'Temperature Overview', 'Temperature Impact on Migration', and 'Summary and Suggestions', which I review individually below. (I exclude review of "Summary and Suggestions", which is purely text included to give the viewer a brief overview of the findings we elaborate more on in this report, and to cite our data.)

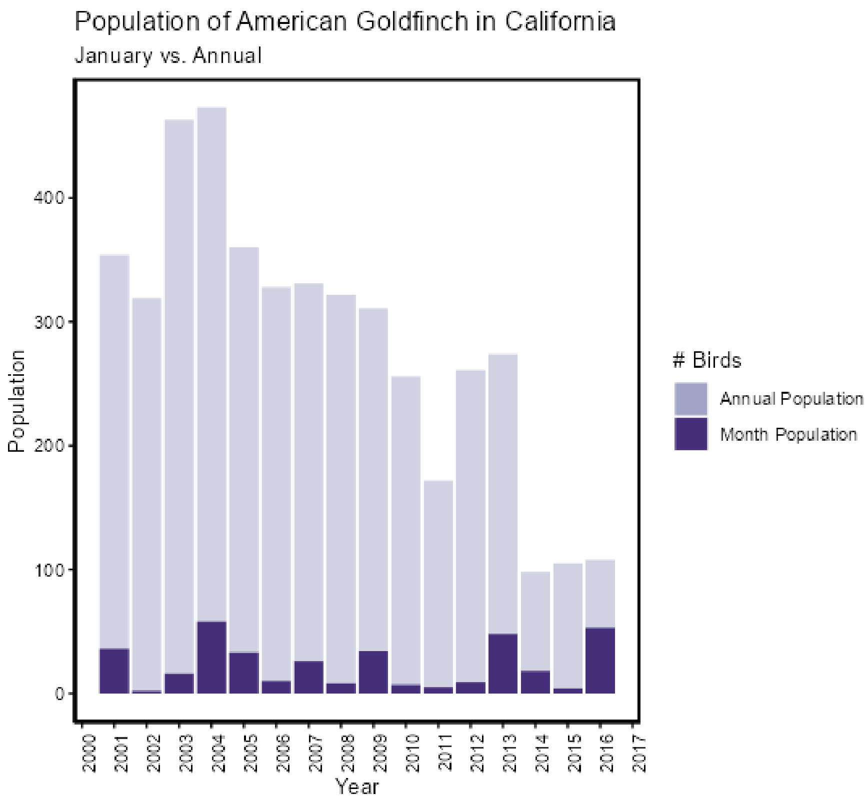
#### 3.1.1 Bird Species Summary

This tab consists of three visualizations which allow the user to visualize bird migration patterns over time, and four interactive fields. The user may select the month, year, species, and state of interest, and the visualizations will update appropriately, as described below.

The first visualization is shown in Figure 3; it shows the monthly and annual population of the chosen bird in the chosen state in the chosen month (over all years).

An interesting finding one may ascertain from this visualization is that the annual population of the American Goldfinch in California is decreasing starkly over this time period; but the proportion that visit in January is increasing. (The natural follow-up question of “why” is left to our hypothetical ornithologist reader!)

**Figure 3: Proportion of Species Population**

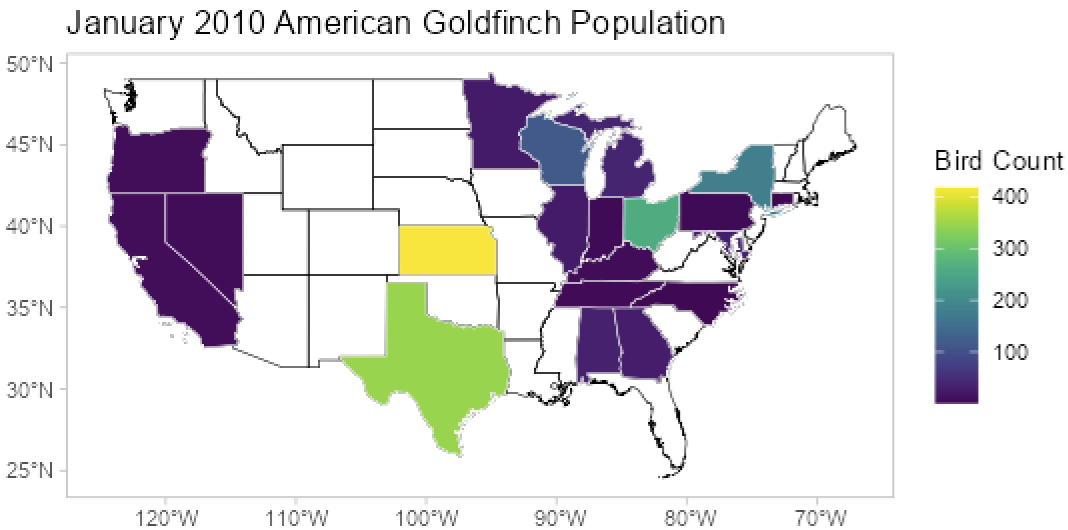


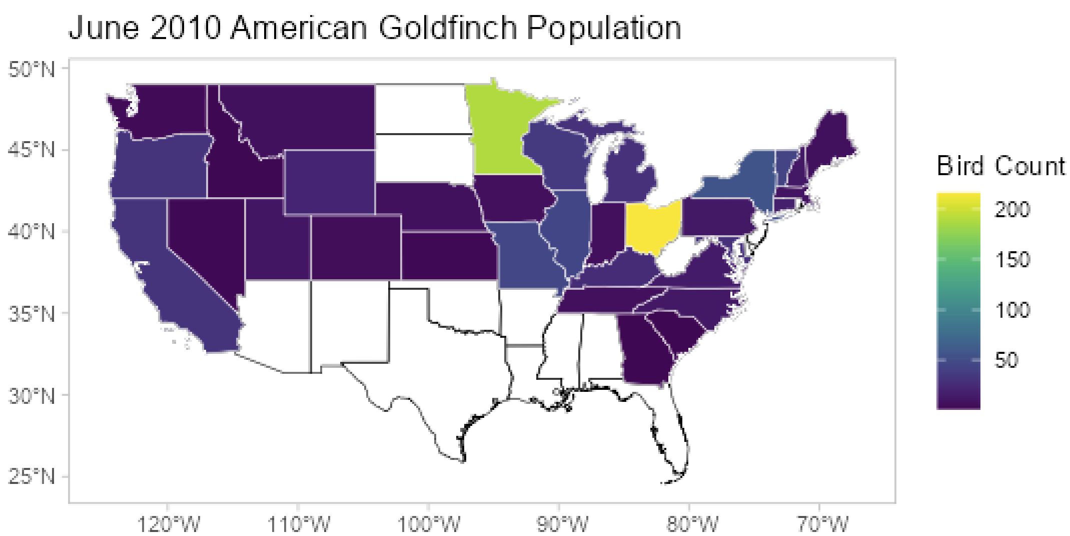

***This bar graph shows the annual and monthly population in the chosen state, for a given species and month.***

Figure 4 on the next page shows two snapshots of the population of the given species in the given year and month. While the first visualization fixed a given spatial point and plotted population over time, this visualization fixes a given temporal point and plots population over space.

An interesting finding that one may ascertain from this graph is that, intuitively, the American Goldfinch populates the northern states (like Minnesota) in the warm month of June, and moves south (to Texas) for the cold month of January.

**Figure 4: Snapshot of Bird Population by State.**



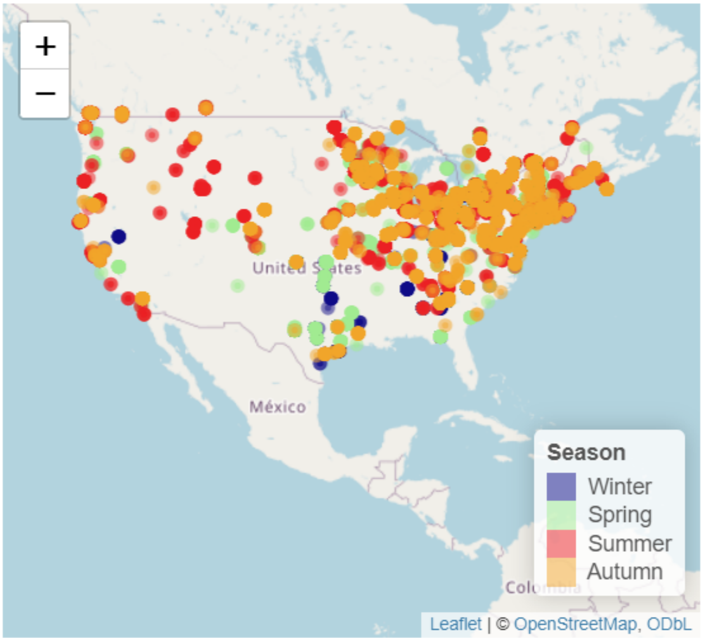




***These maps show the population of the given species in the given year and month in each state.***

Figure 5 below shows the final visualization on this tab; a Leaflet graph which enables zooming and panning, showing all sightings of the given species in the given year, colored by season.

An interesting finding one may glean from this graph is zooming into the Madison area and noticing there are no winter sightings; emphasized by Figure 4 above.

**Figure 5: Snapshot of Bird Sightings.**




***This map provides context for figure 4 above, enabling a deeper look into the data, and facilitates zooming and panning.***

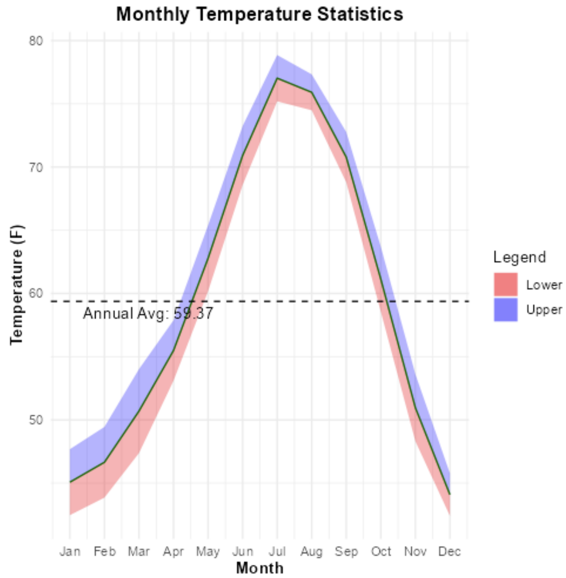
### 3.1.2 Temperature Overview

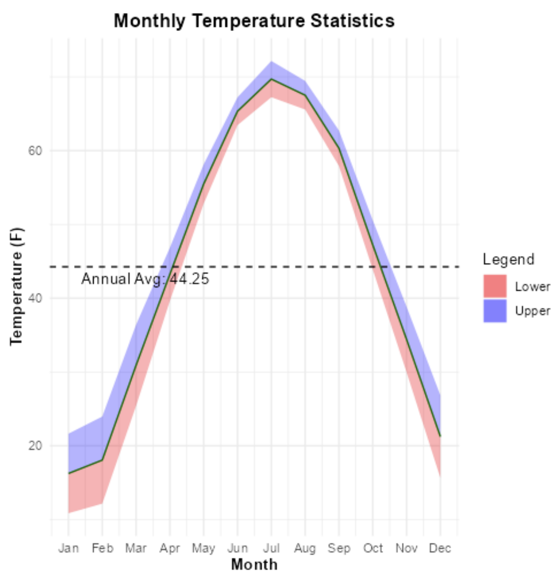
This tab consists of three visualizations (one omitted for brevity) and three interactive fields. The user may choose a month, year, and state, and the visualizations will update appropriately as described below.

Figure 6 below shows the first visualization, which shows the range of temperatures in the given state across the given year. Figure 6 displays this plot with California selected first, and then Wisconsin selected in the second.

Interesting findings one can take away from this visualization is that Wisconsin reaches its peak temperature slightly earlier than California, and its peak temperature/annual average are both about ten degrees lower.

**Figure 6: Yearly Temperature Plot (California vs. Wisconsin)**



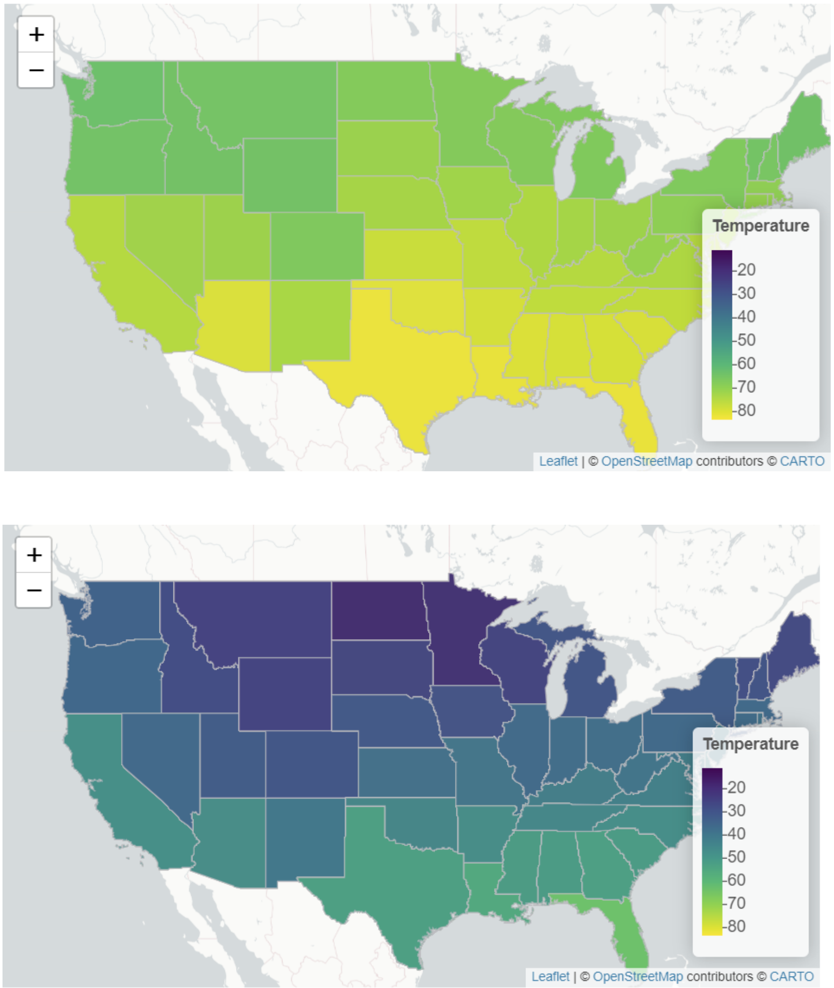




***These plots show the temporal distribution of temperature for California and Wisconsin; notice the earlier peak and lower annotated average for Wisconsin.***

Figure 7 below shows the average temperature for each state in the given month-year; first for July 2023, and then for January 2023. While the first visualization fixes a spatial point and plots temperature over time, this visualization fixes a temporal point and plots temperature over space.

An interesting finding one may glean from this graph is that, due to the graph's fixed temperature scale, it is easy to see that the relative comparisons remain the same across months (i.e. Texas and Florida are always among the hottest states) despite the absolute scale fluctuating (all states are brighter in July than January).

**Figure 7: Spatial Temperature Map.**



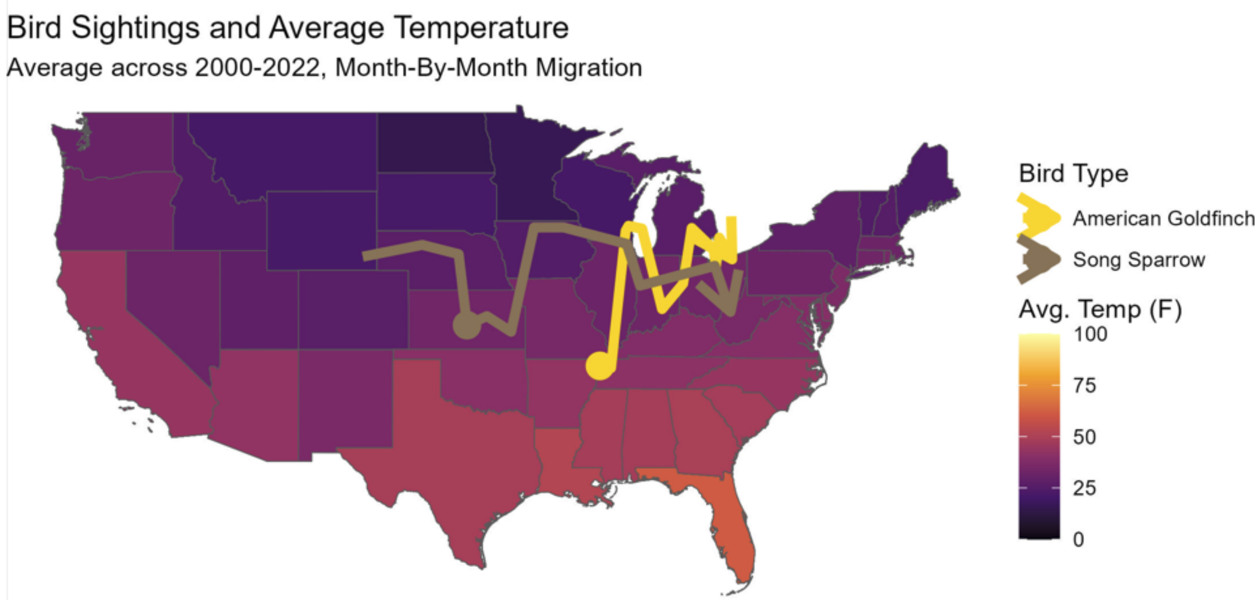

***These plots show the spatial distribution of temperature for July 2023 and January 2023; notice how the fixed scale emphasizes that the relative comparisons remain the same, but the absolute temperatures are lower in January.***

### 3.1.3 Temperature Impact on Migration

The Temperature Impact on Migration tab features three visualizations (two omitted for brevity) intended to combine the findings of the first two tabs, and four interactive fields - month, year range, state (omitted in description), and species. The main visualization of this tab is shown in Figure 8, which overlays the monthly bird migration pattern for each species in the given year range.

An interesting finding one may glean from this visualization is that Song Sparrows tend to migrate east over the course of the year, while the north-south migration of the American Goldfinch is more prominent.

**Figure 8: Spatial Temperature Map Overlaid With Monthly Bird Migration.**




***This map shows a snapshot of temperatures and monthly bird migrations across the continental U.S. for both species. Notice the eastward migration of the Song Sparrow emphasized by this graph.***

### 3.2 Synthesis

The Bird Species Summary tab enables the viewer to observe short-term migration patterns (Figures 3, 4, and 5), as well as study how these migration patterns change over time. One can imagine studying this by visualizing January and June for a recent and a distant year, and see visualize bird sightings (Figure 5). The Temperature Overview tab enables analogous comparisons for temperature instead of bird sightings - both short-term (Figure 6) and long-term (through similar manipulation as described before of Figure 7). Finally, the Temperature Impact on Migration tab combines bird migration and temperature into one cohesive visualization (Figure 8), enabling the user to combine their findings from the first two tabs to infer how bird migration relates to temperature.

## 4. Conclusion

In this report, we first motivated the choices in our app with a survey of existing literature, and then reviewed the implementation of our interface. The interface enables interactive analysis of bird migration and temperature patterns over space and time. More specifically, it can answer queries about short-term and long-term spatiotemporal migration patterns (section

3.1.1), short-term and long-term spatiotemporal temperature patterns (section 3.1.2), and how they relate to each other (section 3.1.3).

## 5. References


1. Chen, Y., Wang, Q., & Chen, S. (2015). Visualizing spatiotemporal patterns of land use changes using a time-varying cellular automata model. Computers, Environment and Urban Systems, 54, 362-376. https://www.mdpi.com/2073-445X/12/8/1525
2. Lu W, Ai T, Zhang X, He Y. (2017). An Interactive Web Mapping Visualization of Urban Air Quality Monitoring Data of China. Atmosphere, 8(8), 148. https://doi.org/10.3390/atmos8080148