Weather and Climate of Utah

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Link to Repository

Background and Motivation

Our team consists of two University of Utah Atmospheric Sciences PhD students with research focusing on precipitation in the western United States. Our projects focus on improving predictions of cool season (November – April) precipitation totals and snow-to-liquid ratios over complex terrain. When it comes to creating these improved forecasts, understanding the climatology of our study domain is necessary; hence, we are proposing to create an interactive visualization to communicate the weather and climate of precipitation and temperature in Utah.

Precipitation is chosen because Utah's water resources rely heavily on cool-season snowfall at high elevations. Mountain snowpack acts as a natural water tower that stores a large fraction of Utah's water resources over the warm months. Specifically, about 53% of the total water runoff in the intermountain west originates as snowmelt from higher terrain, replenishing Utah's reservoirs each spring (Li et al. 2017). Identifying trends in precipitation during the cool season at mountain and valley sites across Utah could allow local water resource managers to act accordingly when planning their water resource distribution plans. Furthermore, extreme precipitation events across regions of complex terrain can produce natural hazards such as flash flooding, landslides, and avalanches, resulting in damage to property, loss of life, and travel disruptions (Steenburgh 2003; Nalli and McKee 2018). Thus, we propose identifying trends in precipitation could be useful for water resource managers and emergency personnel across the state.

Additionally, we focus on temperatures to understand whether there are long-term changes in temperature at some sites or across the state. Temperatures directly determine if precipitation falls in a liquid or solid phase, affecting the total snowpack accumulating over the cool-season. In the warm-season, increased temperatures can result in enhanced wildfire activity across the western U.S. (e.g., Westerling et al. 2006), although this is not always the case. We aim to identify potential trends in temperature as well as wildfire activity at observing sites across Utah to check for any correlation between them. This information can be used by emergency and wildfire personnel to plan when the most resources should be used during the wildfire season.

Project Objectives

The overarching objecting of our project is to produce a visualization to communicate the climatology of precipitation and temperature for Utah. The questions we will answer are:

- What is the climatological distribution of monthly average temperatures and precipitation at observation stations across Utah?
- Is there a climatological trend in precipitation and temperature at observation stations across Utah? Is there a decrease in precipitation and an increase in temperatures?
- What is the climatological gradient of precipitation and temperature with elevation by month? How does it vary by month?

- Are there relationships between precipitation and temperature trends with natural resources and the occurrence of natural hazards?

We hope to build a stronger understanding of the climatology of Utah using our visualizations. The benefit of the visualizations is to communicate with non-atmospheric scientists the trends in precipitation and temperature, how terrain may affect these trends, and the implications towards natural hazards and resources.

Data

Listed below are the datasets we plan to use in our project. These data providers allow us to download CSV files of the listed datasets.

Variable	Dataset Provider	Notes
Precipitation	National Water and Climate Center	Monthly and yearly precipitation data at Utah sites with data available from 1992 to 2022
Temperature	National Water and Climate Center	Monthly and yearly temperature data at Utah sites with data available from 1992 to 2022
Wildfire Acres	Utah DNR	Historic Utah Wildfire Perimeters: 1999 to 2020
GSL Water Levels	USGS	Great Salt Lake at Saltair Boat Harbor, UT water surface elevation from 2007 to 2023

Data Processing

A substantial clean-up of the data is unlikely; most often observational meteorological data is pre-processed before archived. Initial steps will be to pull observational data from as many stations as possible with a threshold of greater than 30 years of data. The variables we will be primarily working with are observational temperatures and precipitation. To clean-up the precipitation data, we will:

- Pick observation stations with more than 30 years of data
- Remove any precipitation days that are zero or contain fill a value (i.e., -9999 or some very large or small number)
- Pre-process the climatology statistics in python (e.g., monthly and yearly total)

And to clean-up the temperature data, we will:

- Pick observation stations with more than 30 years of data
- Filter out temperatures that are above or below three standard deviations
- Determine what the data fill value is (i.e., -9999 or some very large or small number) and set them to NaNs
- Pre-process climatology statistics in Python (e.g., monthly and yearly mean)

To clean-up the wildfire data, we will:

- Use the fire start date as the year identifier
- Remove fires of less than one acre
- Remove any fires with missing start date or acreage
- Pre-process statistics in Python (e.g., total acres per year)

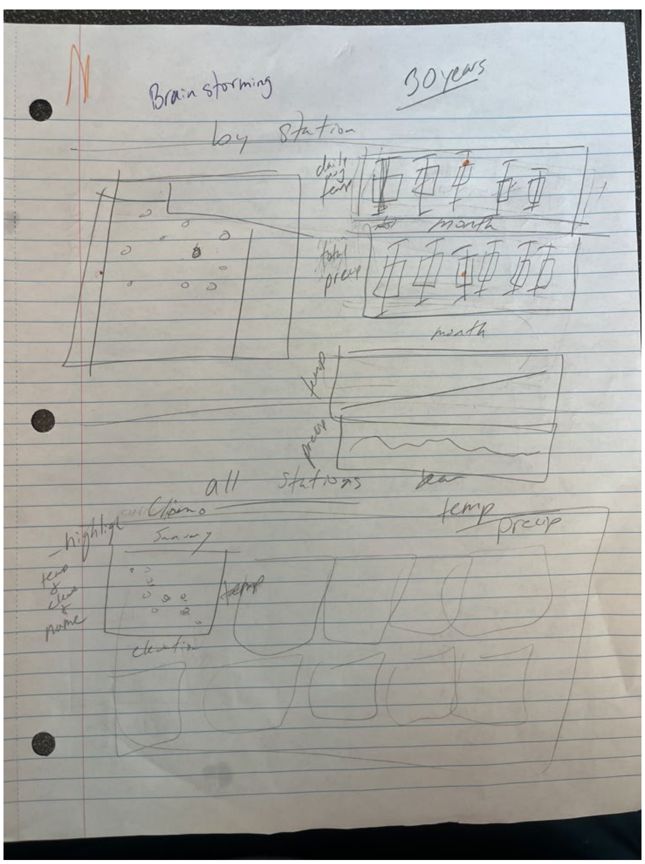
To clean-up the Great Salt Lake water elevation data, we will:

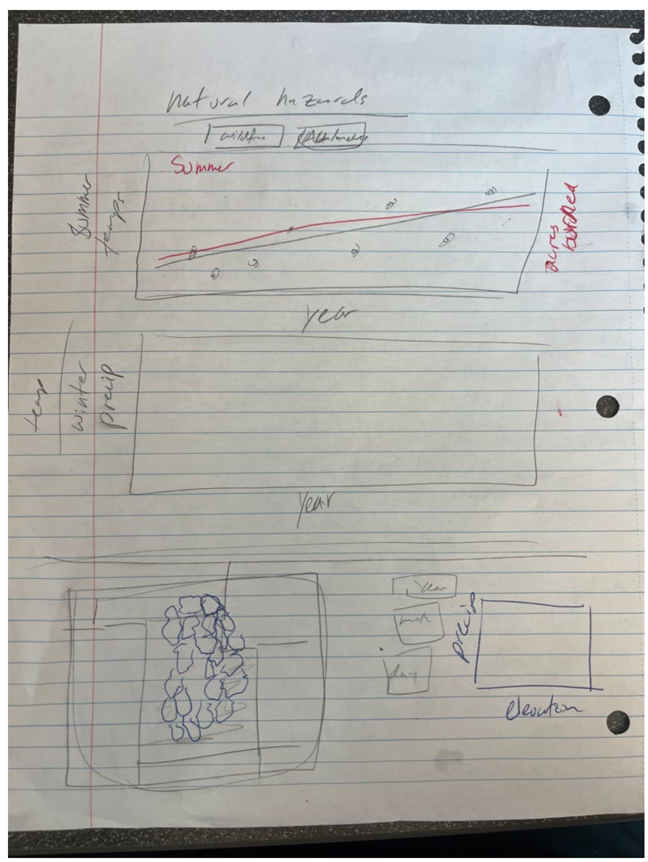
- Determine what the data fill value is (i.e., -9999 or some very large or small number) and set them to NaNs
- Pre-process statistics in Python (e.g., monthly or yearly water elevation)

Visualization Design

Below, we've included the sheet we used to brainstorm, three visualizations and their prototypes (Separated by numbers and then letters for each prototype), and one final design.

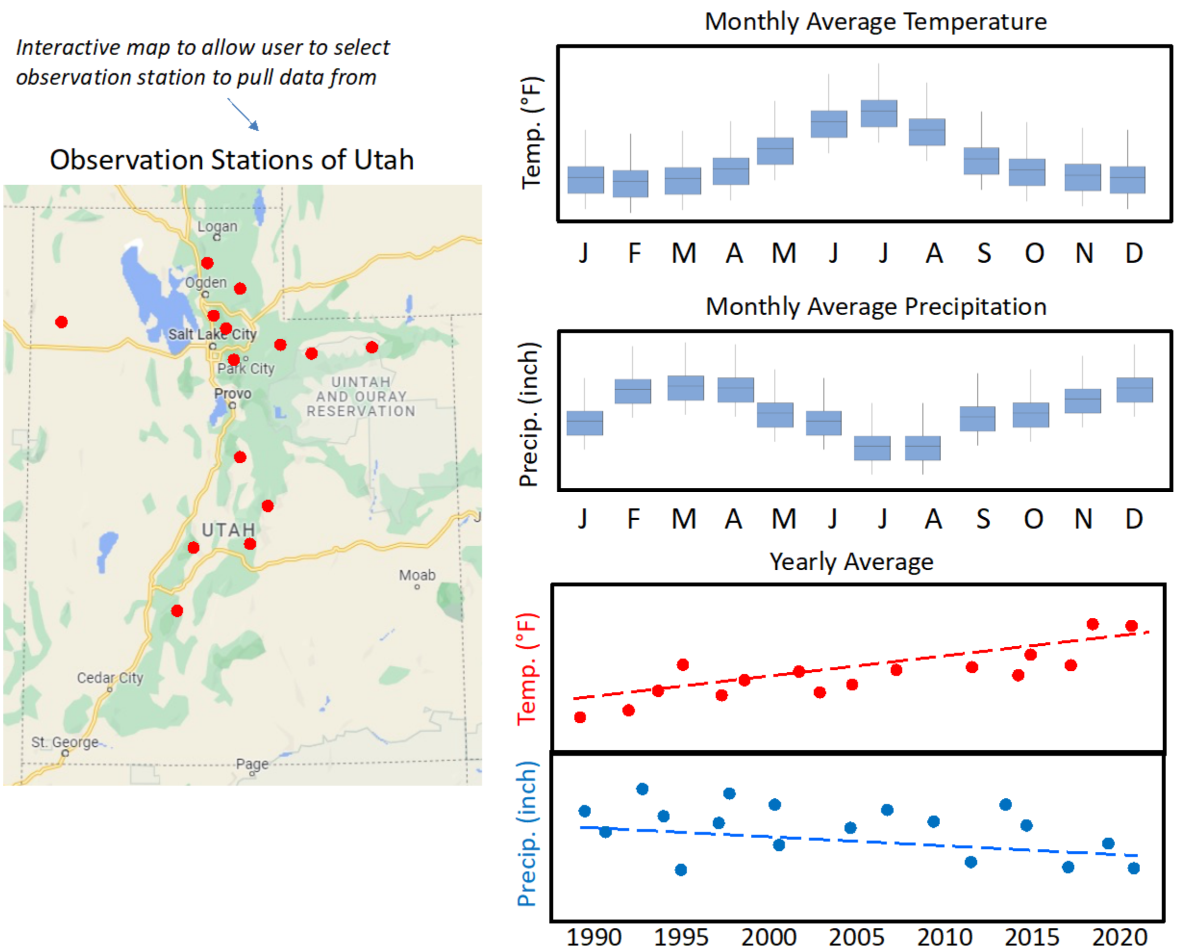
Brainstorming





1. Interactive map of Northern Utah observing sites containing temperature and precipitation climate data

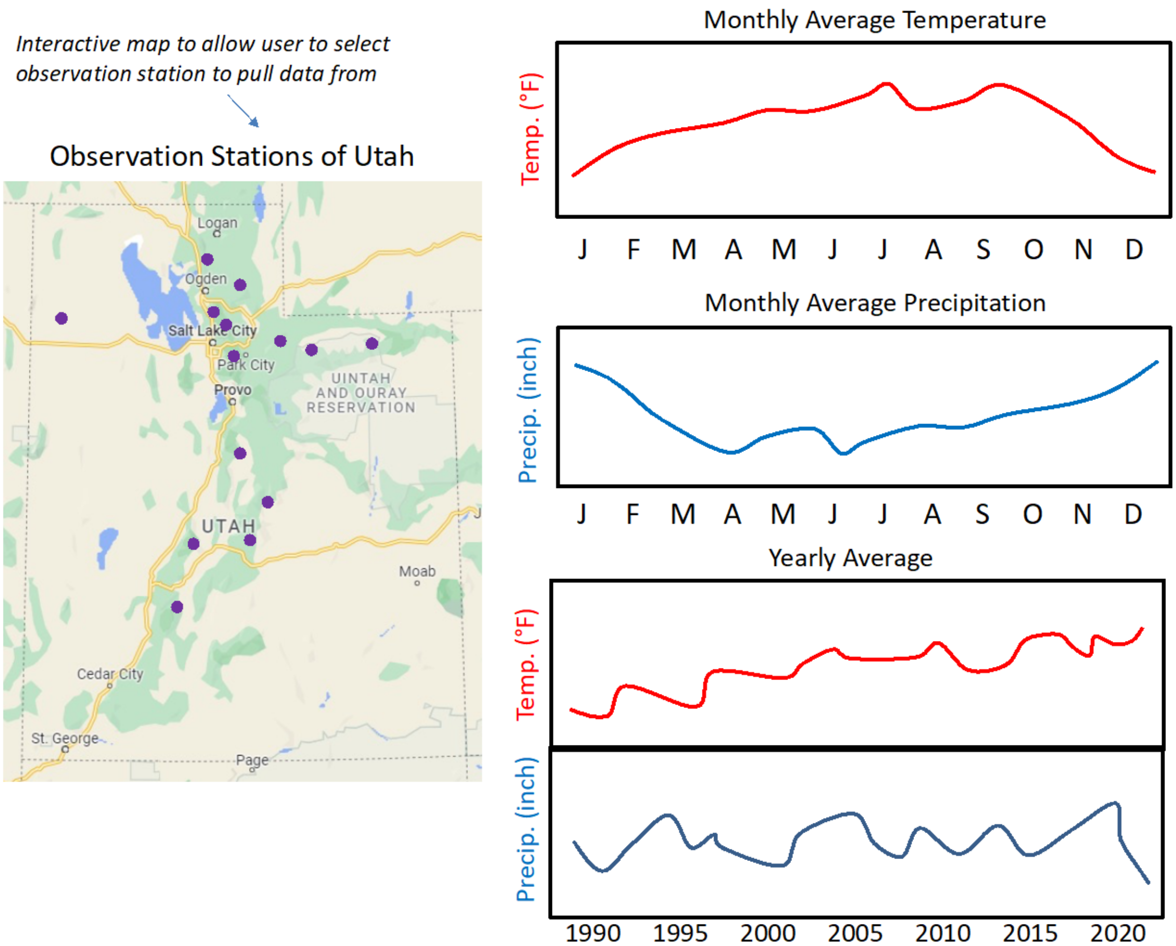
    a. Box and whisker charts of monthly average temperature and precipitation and scatterplots of yearly averaged temperature and precipitation from 1992 to 2022



Design: The top two plots are box and whisker charts of monthly average temperature and precipitation for the selected site from the interactive map on the left. The bottom two plots are scatterplots of temperature and precipitation and line of best fit for the selected site from the interactive map on the left.

Visual encodings justifications: We use a map to allow the user to visualize the location of each station used in the dataset. Box and whisker charts show the monthly variability in each variable. Scatterplots show trends and outliers for each variable and the line of best fit allows the user to easily visualize any trends over time.

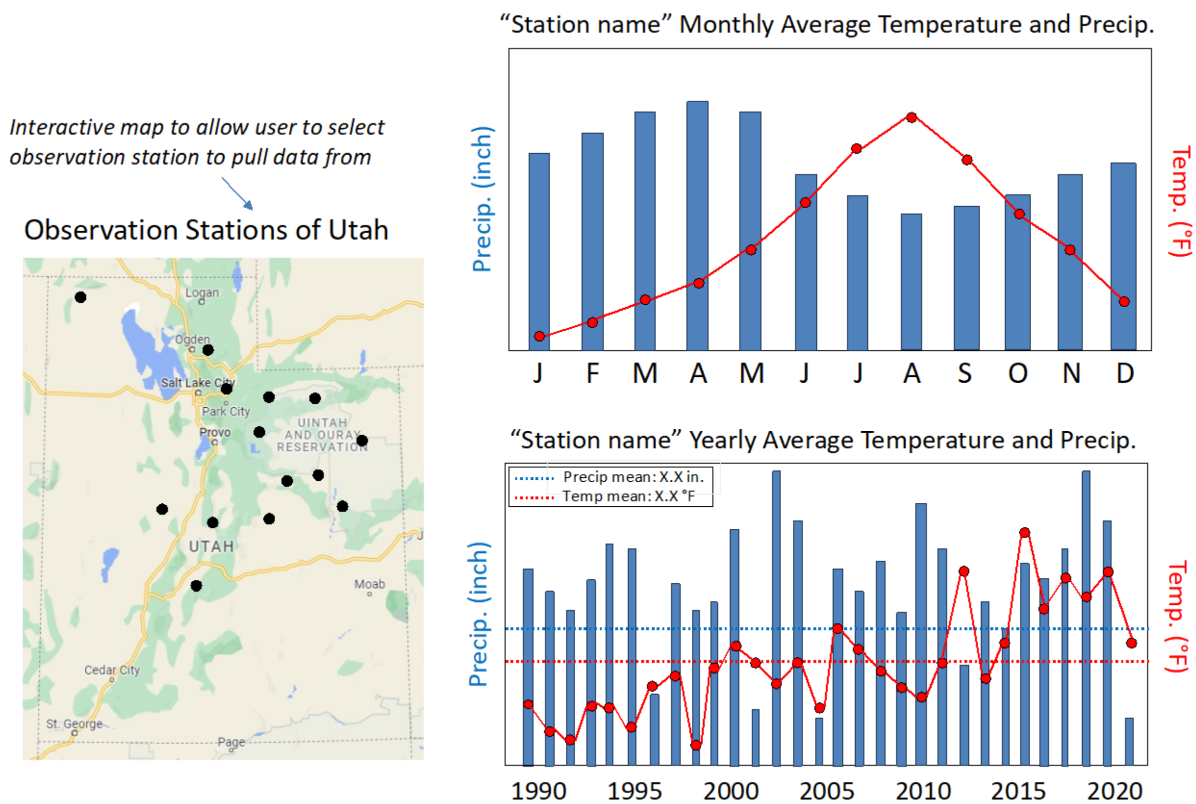
b. Line charts and standard deviations of monthly average temperature and precipitation and line charts of yearly average temperature and precipitation



Design: The top two plots are line charts and standard deviations of monthly average temperature and precipitation for the selected site from the interactive map on the left. The bottom two plots are line charts of yearly average temperature and precipitation for the selected site from the interactive map on the left.

Visual encodings justifications: We use a map to allow the user to visualize the location of each station used in the dataset. Line charts allow the user to easily detect any monthly trends in each variable and shading of monthly standard deviations visualizes when the most monthly variability occurs. Similar to the scatterplots on the previous page, time series of yearly average temperature and precipitation using a line chart also allow the user to easily visualize any trends.

c. Bar chart of monthly average precipitation and line plot of monthly average temperature plotted simultaneously for selected site. Second plot is a bar chart of yearly average precipitation and line plot of yearly average temperature from 1992 to 2022 plotted simultaneously with means plotted for selected site.

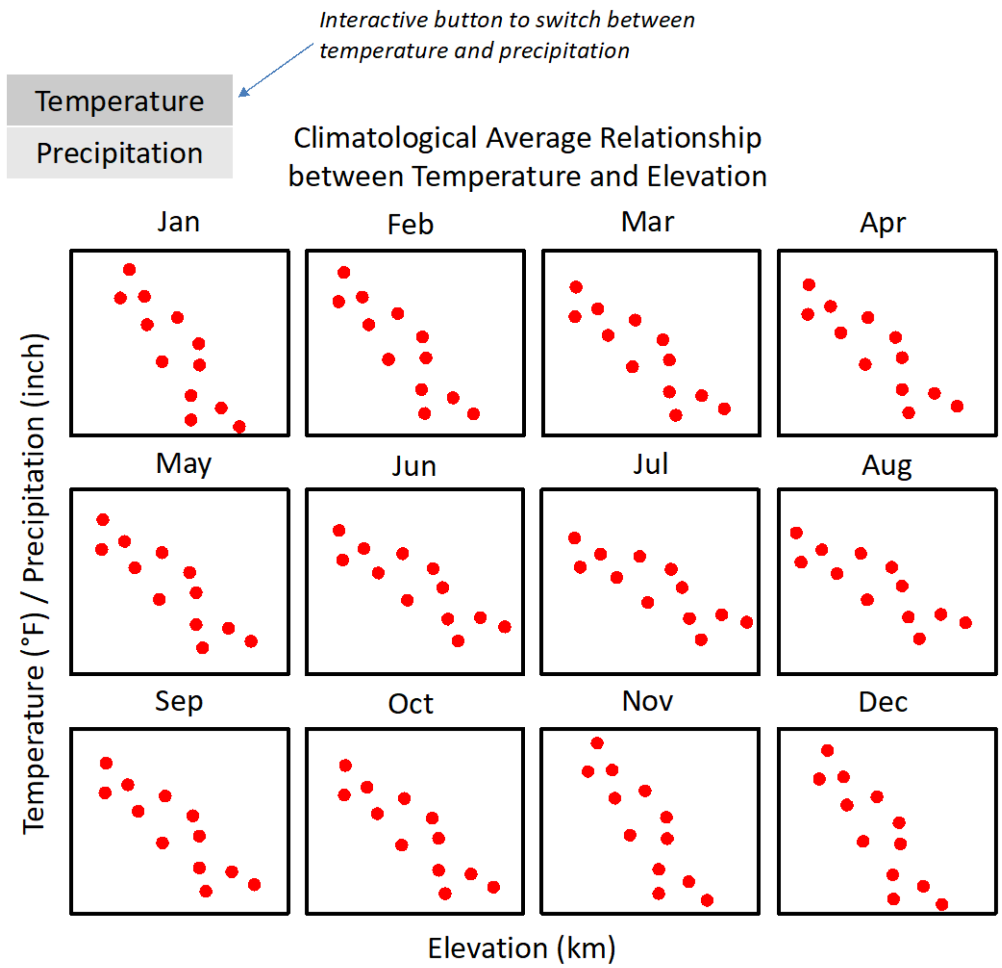


Design: The top plot is station monthly average precipitation as a bar chart and monthly average precipitation as a line chart. The bottom plot is station yearly average precipitation as a bar chart and yearly average temperature as a line chart with means of both variables plotted as a horizontal dashed line. The legend in upper left contains the means.

Visual encodings justifications: Here, we combined the precipitation and temperature plots into one for cleanness and brevity. Combining both plots may allow the user to note trends in both variables and any relationships between the two. Including the means also allows the user to easily identify years when the precipitation or temperature were above or below average. Lastly, we use a map to allow the user to visualize the location of each station used in the dataset.

2. Composite plots of temperature and precipitation vs. elevation

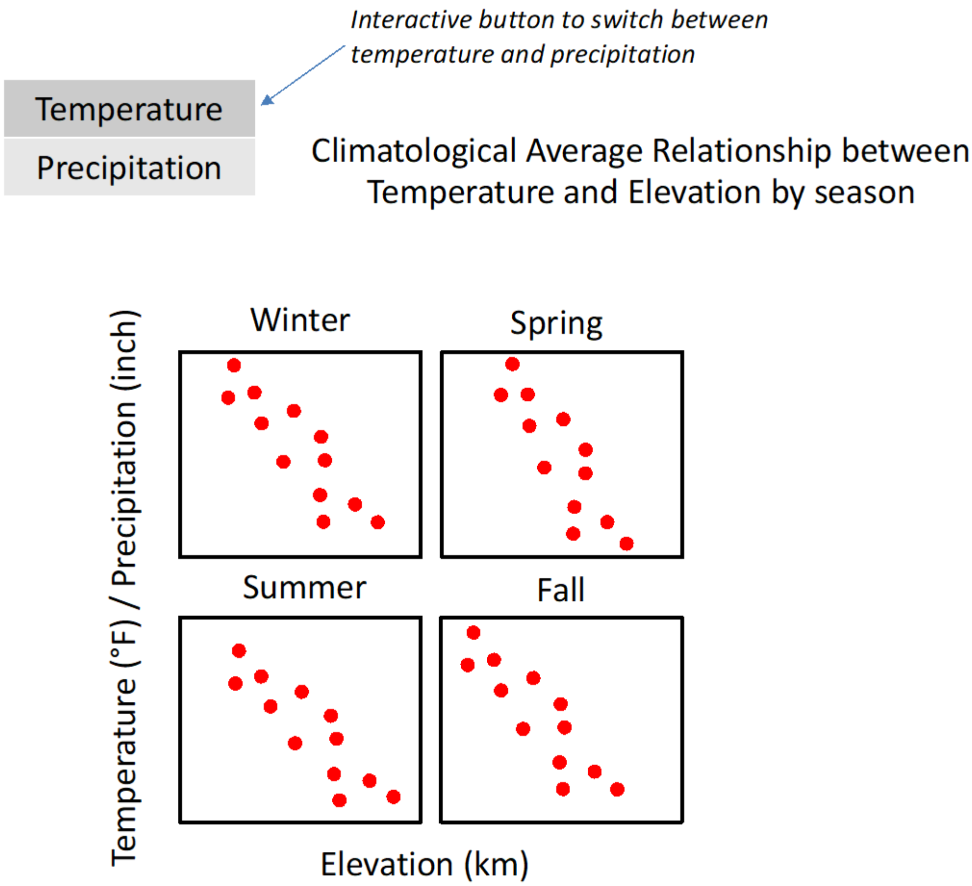
    a. Scatterplots of monthly mean temperature vs. elevation or monthly mean precipitation vs. elevation for the selected site 1992 - 2022



Design: Simple scatterplots of either climatological average temperature vs. elevation or climatological average precipitation vs. elevation for each month for all sites used in the project. The user can toggle between temperature and precipitation using a button above the scatterplots.

Visual encodings justifications: Visualizing the relationships between temperature vs. elevation and precipitation vs. elevation by month using scatterplots allows the user to understand when the largest and smallest differences in each variable occur each year across the state of Utah. The simple button used to toggle between the variables is easily noticeable provides easy access to switch between the variables.

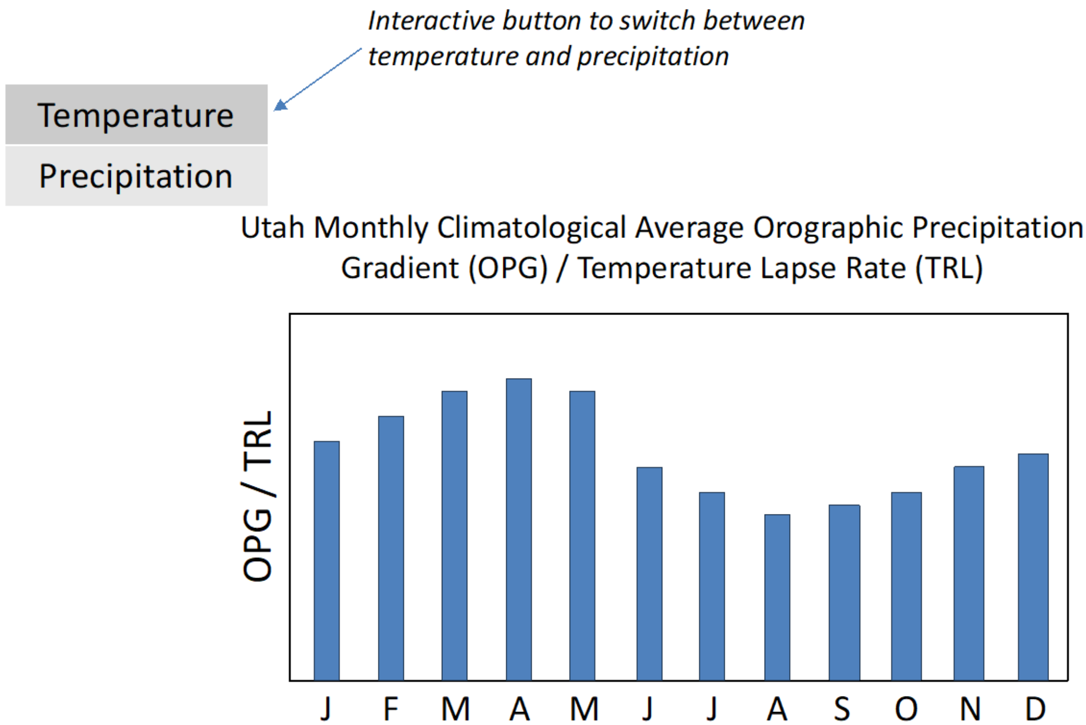
b. Scatterplots of seasonal-mean temperature vs. elevation or seasonal-mean precipitation vs. elevation for the selected site 1992 – 2022



Design: Simple scatterplots of either climatological average temperature vs. elevation or climatological average precipitation vs. elevation for each season for all sites used in the project. The user can toggle between temperature and precipitation using a button above the scatterplots.

Visual encodings justifications: Instead of visualizing the scatterplots by month, we plot the data by season. The user may prefer this instead if they are curious about the relationships over seasons instead of a single month.

c. Bar chart of monthly climatological average orographic precipitation gradient (OPG) or temperature lapse rate (TRL)

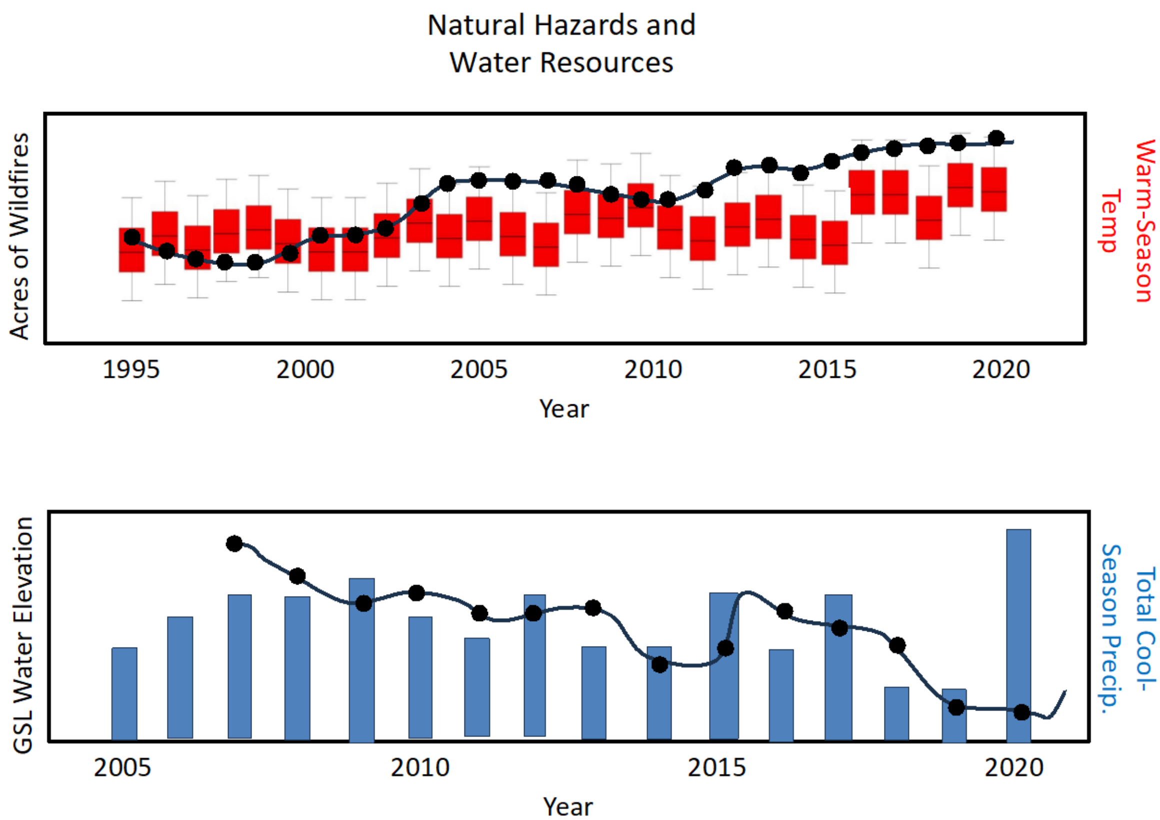


Design: Bar chart of monthly climatological orographic precipitation gradient (OPG) or temperature lapse rate (TRL) averaged over each site in Utah that can be toggled using a button above the plot.

Visual encodings justifications: One can calculate the OPG and TRL using the precipitation vs. elevation relationship and the temperature vs. elevation relationships. A user may prefer this over the scatterplots if they want to see the statewide average of each variable.

3. Visual relationships between the climatology and the occurrence of natural hazards and changes in water resources of Utah

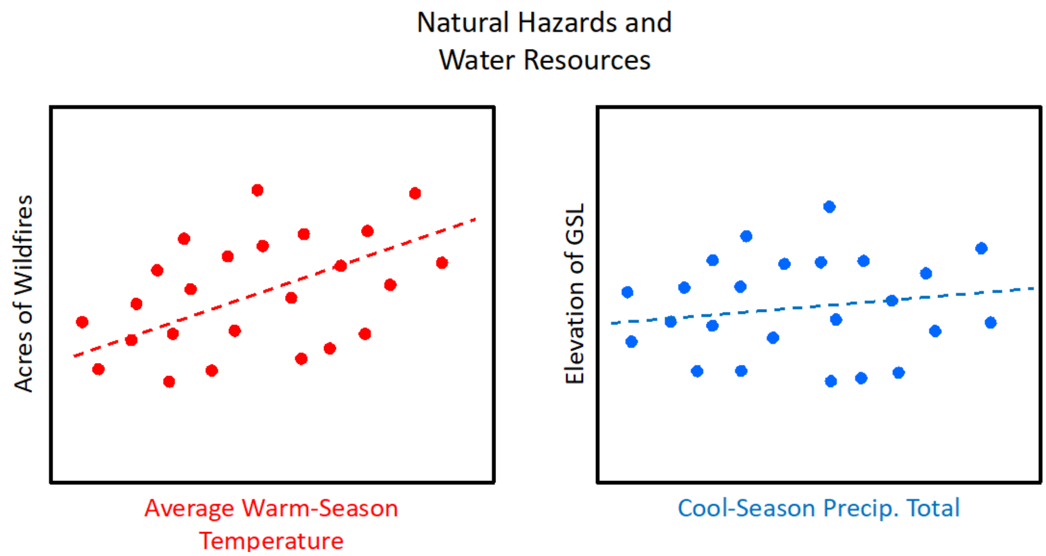
    a. Relationship between warm-season temperatures and acres of wildfires burned across Utah and the relationship between total cool-season precip and the Great Salt Lake (GSL) elevation for sites that contribute to the GSL's water levels



Design: The top plot visualizes the relationship between the yearly statewide average temperature and the number of acres burned across Utah for each year. The box and whisker charts of yearly temperature visualizes the yearly temperature variability. The bottom plot is a bar chart of total cool-season precipitation and GSL water elevation.

Visual encodings justifications: As temperatures increase, wildfire activity tends to increase as well. The top plot could reveal relationships between temperature and wildfire activity using the number of acres burned across the state. Although not always the case, a user could also see the relationship between the GSL elevation and the total cool-season precipitation each year for the sites that contribute to the GSL's elevation.

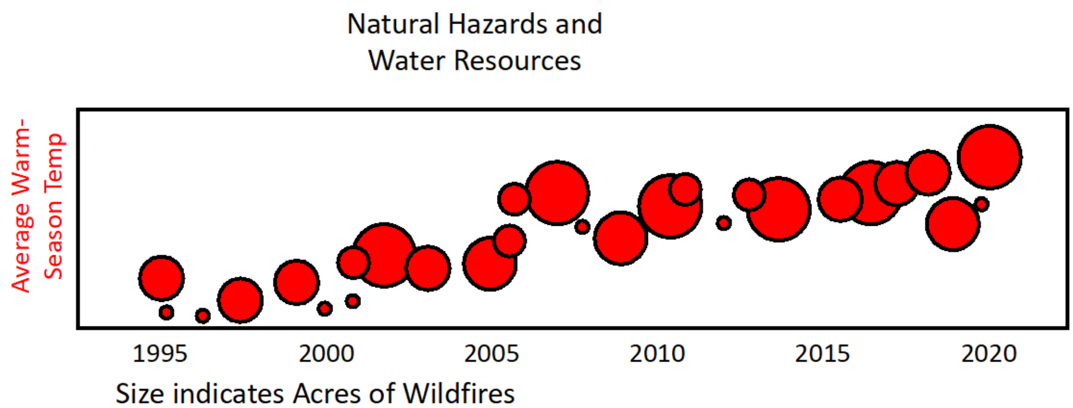
b. Scatterplot of average warm-season temperature vs. acres of wildfires burned each year and a scatterplot of

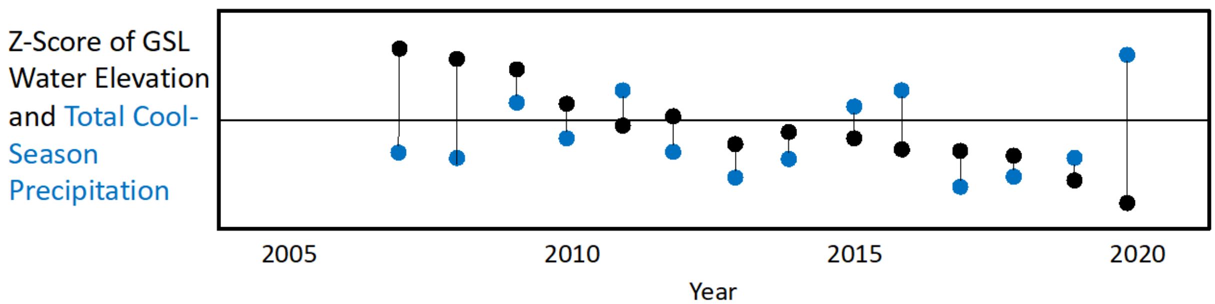


Design: The left scatterplot visualizes the relationship between the average-warm season temperature vs. acres of wildfires burned each year across Utah as well as the trend (if any) using a best fit line. The right scatterplot visualizes the relationship between the cool-season precipitation total each year vs. the elevation of the GSL as well as the trend (if any) using a best fit line.

Visual encodings justifications: To show potential trends in temperature and precipitation vs. natural hazards, we plotted them against wildfires and the elevation of the GSL respectively. We expect to see an increase in wildfire activity with temperatures, but likely a modest increase in GSL elevation with increased cool-season precipitation totals.

c. Time series of average warm-season temperature with points that scale with acres of wildfires and relationship between GSL water elevation and total cool-season precipitation using Z-Scoring





Design: The top plot is a time series scatterplot of average warm-season temperature across Utah with points that scale with the acres of wildfires burned each year. The bottom plot is the Z-Scores of the GSL water elevation and total cool-season precipitation each year.

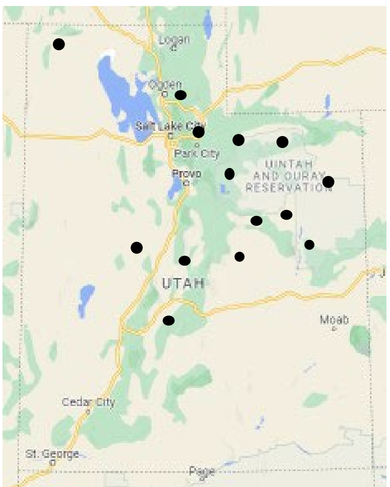
Visual encodings justifications: We chose the top plot as it nicely visualizes both a trend (if any) in average-warm season temperatures as well as the number of acres burned each year. A user may prefer the bottom plot over the previous prototypes if they are more inclined to see relationships using statistics instead of actual values.

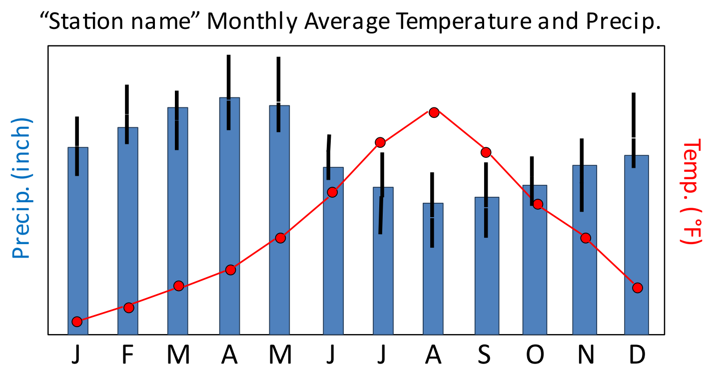
Final Visualization Design:

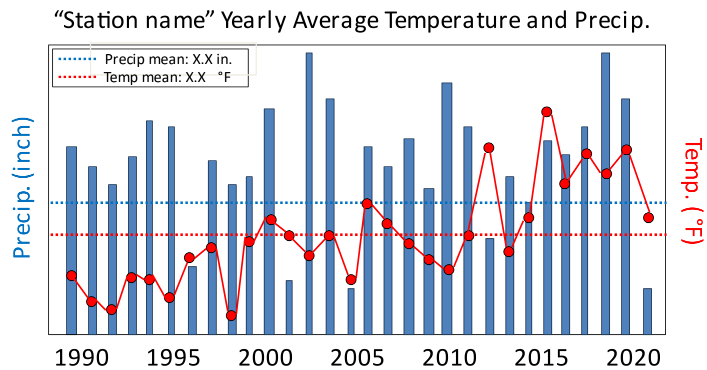
1. Interactive map of Utah observing sites containing temperature and precipitation climate data.

Interactive map to allow user to select observation station to pull data from

Observation Stations of Utah



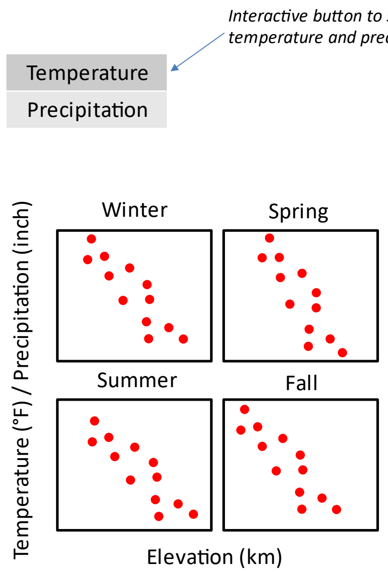




Design: The map on the left side will be interactive, allowing the user to select observation stations. The two plots illustrate the monthly and yearly values of precipitation totals and temperature averages. The black line on top of the monthly precipitation total bar chart indicates the upper and lower quartile of observations. The legend in the upper left contains the mean values.

Visual Encoding Justifications: Using black circles to select the observation station allows for high contrast between it and the map. We decided that layering the precipitation and temperature data was best because it allows the user to compare the seasonality and yearly variability of the two variables together. For the monthly plot, the black line was added to indicate the upper and lower quartile, since we wanted to keep the ability to inspect the monthly variability in precipitation, similar to the box and whisker plots. For the yearly plot, including the mean values allow the user to easily identify the years in which precipitation and temperature diverged from the average. Blue was selected for precipitation, since water is often identified with blue shading, and red was chosen for temperature to create high contrast in the color hues. These hues will be consistent throughout the webpage.

2. Scatter Plots of seasonal mean temperature VS elevation or seasonal mean precipitation vs elevation for the selected site 1992 – 2002



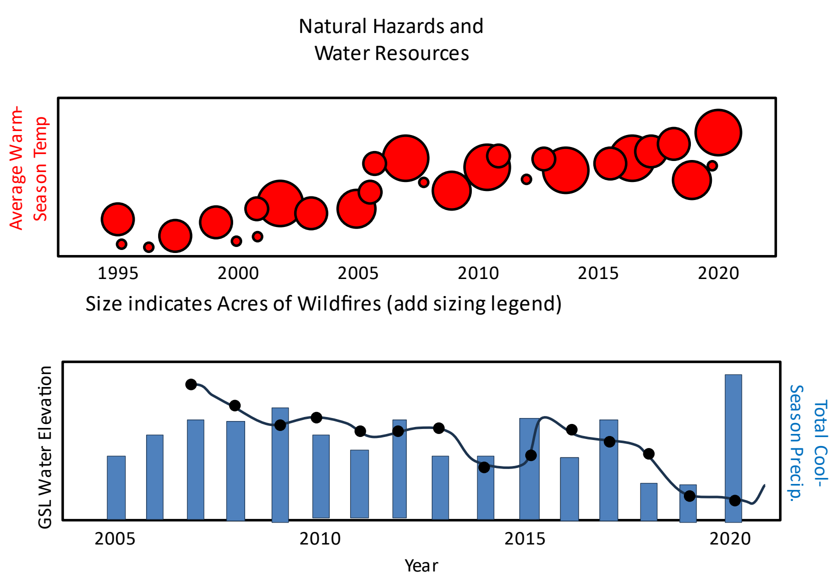
Statistics:

	DJF	MAM	JJA	SON
Orographic Gradient	...	...	...	...
Variance of Orographic Gradient	...	...	...	...
R2	...	...	...	...

Design: This visualization will include a button to allow the user to switch between temperature and precipitation. The buttons will cause four scatter plots to appear, one for each season, indicating the relationship between elevation and the selected value. There will also be a table indicating statistics of the relationship by season. Orographic gradient (OG) is the linear relationship, variance will indicate the total variance of OG within the season. and R2 will show how strong the relationship is.

Visual encodings justifications: Plotting by season is easier for the user to compare than by month and this relationship varies more by season. Additionally, we decided to add a table to display statistics of these relationships to allow the user to compare quantities of precipitation and temperature gradients with elevation.

3. Visual relationships between the climatology and the occurrence of natural hazards and changes in water resources of Utah



Design: The top plot is a timeseries scatterplot of the average warm-season temperature across Utah. The size of the scatter plot circles scale with the total acres burned by wildfires that season. The bottom plot is a bar chart of the total cool-season precipitation and the line plot shows the water elevation of the Great Salt Lake.

Visual encoding justifications: We chose scalable scatter plot bubbles to indicate the acres of wildland burned; this allows us to show spacial size using the actual size of the plots. We felt that the box plot to indicate precipitation totals was the easiest to read and understand. The relationship between cool-season precipitation and the water level of the GSL is not as directly related, so we kept the plotted style between to two separate. Additionally the color of the line plot was kept different than the first climatology plots to prevent confusion.

Must-Have Features

- Clickable map of Utah with the locations of observation stations. This will allow users to select an observation station to view its climatology of precipitation and temperatures.
- A composite from all observational stations – monthly plots of the relationship between precipitation and temperature by elevation.
- Plots to show if a visual relationship between the climatology and the occurrence of natural hazards are shown in Utah.

Optional Features

- Pulling live data to be plotted on-top of the climatological distributions of precipitation and temperature to allow for a live comparison.
- An interactive map to allow the user to select mountain faces over Utah to display the climatology of orographic precipitation gradients for that area.

Project Schedule

Week 5 Sep 19/21	Project Review with staff
Week 6 Sep 26/28	Collect and process necessary data (precipitation, temperature, natural hazards, etc.)
Week 7 Oct 3/5	Code the background processes of the website, i.e., loading in data, switching from page to page, CSS styling
Week 8 Oct 10/12 Fall Break	Finish coding background processes and begin page containing interactive Utah map with climatology of observation stations
Week 9 Oct 17/19	Finish coding page with interactive Utah map with station climatology. Begin page containing relationship between precipitation and temperature with elevation
Week 10 Oct 24/26 No Class	Finish page containing relationship between precipitation and temperature with elevation. Polish current product for next week's milestone
Week 11 Oct 31/Nov 2 Milestone	*Have completed data acquisition, have data structures in place, hand in process book and code. Have prototype completed, you must not have all your views up and running, but the direction of the content must be clear*
Week 12 Nov 7/9 Peer Feedback	Complete page containing the relationships between precipitation, temperature, wildfires, and water resources
Week 13	Implement the suggestions of peer review

Nov 14/16	
Week 14 Nov 21/23 Thanksgiving	A buffer week; a week to fix any issues, add additional interactivity, etc.
Week 15 Nov 28/30 Final Project Submission	Pull together the following items and turn in assignment: • *Code* - All web site files and libraries assuming they are not too big to include • *Data* - Include all the data that you used in your project. If the data is too large for github store it on a cloud storage provider, such as Dropbox or Google Drive. • *Process Book* - Your Process Book in PDF format. • *README* - The README file must give an overview of what you are handing in: which parts are your code, which parts are libraries, and so on. The README must contain URLs to your project websites and screencast videos. The README must also explain any non-obvious features of your interface.