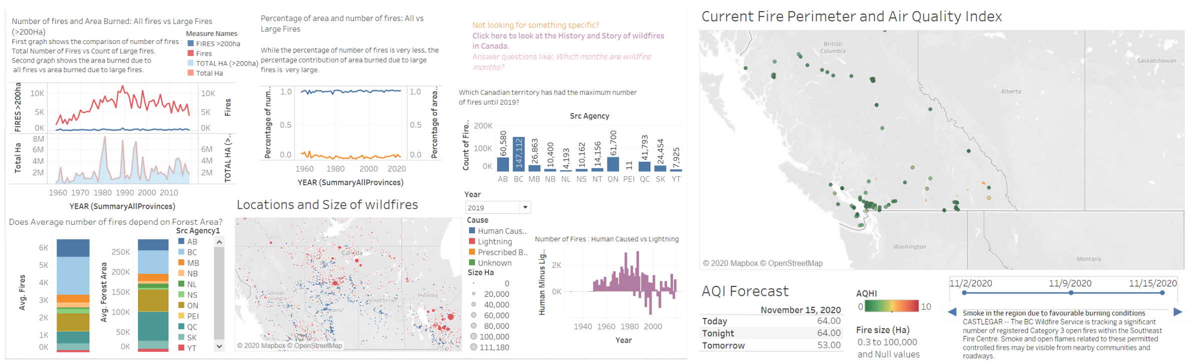
Firest: Visualizing the Current State and Impact of Wildfires Across Canada

Hannah Elbaggari, Preeti Vyas, Roopal Singh Chabra, and Rubia Guerra



(a) Historical Tab

(b) Current Tab

Fig. 1: Updated views of the Historical and Current Tab. (a) The Historical Tab shows charts and maps that enable a user to view results of analysis of the historical wildfire data. (b) The Current Tab plots an interactive map of the most recent wildfire perimeters and AQHI readings by monitoring site.

Abstract—Wildfires are a pressing natural disaster impacting the entire world. People can benefit from a comprehensive visualization not only representing the wildfires but also their effects on air quality and connection with changing climate patterns. Data related to fire parameters, affected areas, evacuated areas, exist either in survey data form or via satellite datasets. There are also related resources that can be employed to better understand the impact of wildfires and its correlation with climate change, for e.g., air quality index, smoke map, weather patterns drawn from historical data. This project aims to integrate multiple variables of interest regarding wildfires in one dashboard, facilitating access to wildfire related information. The scope is currently limited to Canada.

Index Terms—Wildfires, design study, analysis

1 Introduction

As the global climate changes, wildfires are projected to become more frequent, resulting in longer, more destructive fire seasons. The occurrence, frequency and behaviour of wild-land fires have varied dramatically over time and space, largely due to the dynamic consequences of climate change and climate instability [24]. Additionally, there are expected shifts in wild-land fire patterns. Climate change in the 21st century is likely to result in more intense fires in many boreal forests, with significant environmental and economic implications. Other contributing factors are changes in land use, vegetation composition, and firefighting (meaning fire suppression) efforts [13]. Fire causes detrimental climate change every year, and to combat this we must first understand the current state of fire impacts and their ties to the historical climate patterns.

As the west coast is hit hard by wildfires, every year several campers and residents are trapped in life threatening situations, and there is an immense loss of property and life. Wildfires have also adverse effects on health due to air quality and exposure to toxic pollutants. Smoke emerging from these fires contains particulate matter, carbon monoxide, nitrogen oxides, and various volatile organic compounds (which are ozone precursors). These pollutants can significantly reduce air quality, both locally and in areas downwind of fires [26]. Forest fires consume millions of acres of land, destroying thousands of homes and properties in the Western United States and around the world. Fires like the 100,277-hectare Lutz Creek fire in British Columbia in August 2018 and the CampFire in California in November 2018, which burned more than 142,000 acres, exact a costly economic and human toll [18]. Analysis of wildfire data often helps in understanding the patterns of wildfires to try and minimize their risk.

Current approaches to fire visualizations do not provide the boundaries and other associated important information like smoke, visibility, and air quality in one comprehensive interactive map. As this information is interconnected, compiling it together in one resource may help the users to estimate and understand consequences of fires in concerned areas. For example, the fires that were experienced in Washington, U.S.A, this year had direct impacts on the air quality in Vancouver, Canada due to their proximity and wind patterns. A comprehensive visualization will also be valuable for frequent campers who can use it as a guide to make informed decisions and residents who can be warned about the fire proximity and air pollution levels in their neighbourhoods.

Additionally, current examples of wildfire visualizations do not provide the historical data to help grasp the climate impact of the fire season. Each year wildfires increase in size and frequency, but without the direct comparison of data it is hard to understand the impacts they have over the course of years. This problem could be mediated by visualizing historical datasets presenting the cause-effect situation in case of wildfires. We know that factors like climate change cause more severe wildfires [24], and vice-versa, creating a torrential climate change snowballing effect. We propose to centralize air quality, smoke

- *Hannah Elbaggari. E-mail: hre@cs.ubc.ca.*
- *Preeti Vyas. E-mail: pv@cs.ubc.ca.*
- *Roopal Singh Chabra. E-mail: roopal@ece.ubc.ca.*
- *Rubia Guerra. E-mail: rubiarg@cs.ubc.ca.*

Manuscript received xx xxx. 201x; accepted xx xxx. 201x. Date of Publication xx xxx. 201x; date of current version xx xxx. 201x. For information on obtaining reprints of this article, please send e-mail to: reprints@ieee.org. Digital Object Identifier: xx.xxxx/TVCG.201x.xxxxxxx

plumes, active fires, and historical climate data to be viewed in a single dashboard.

2 Related Work

2.1 Existing Wildfire Maps

One of the national portals for viewing information about wildfires is the Canadian Wildland Fire Information System (CWFIS) provided by the Government of Canada [10]. This resource provides various dataset, such as fire weather maps, fire behaviour maps and fire M3 hotspots as shown in Fig. 2. According to information available in this system, the fire weather maps visualize the fire danger which is a relative index of ease of vegetation ignition, difficulty of fire control and extent of fire damage. The fire behaviour maps use the head fire intensity (HFI) which is the predicted intensity, or energy output, of the fire at the front or head of the fire. Fire M3 plot hotspots, that is, a pixel with a high infrared intensity satellite image, suggesting a heat source. It may represent a single fire or may represent a larger fire as one of many hotspots. As an initiative of the Canada Centre for Remote Sensing and the Canadian Forest Service, the Fire Monitoring, Mapping, and Modeling Framework (Fire M3) began operations in 1998 [10]. Fire M3's objectives are to use low-resolution satellite imagery to classify and locate regular actively burning fires; to measure the burned area regular and annually; and to model the fire activity and consumption of biomass from fires.

2.2 Visualization of Wildfire Related Parameters

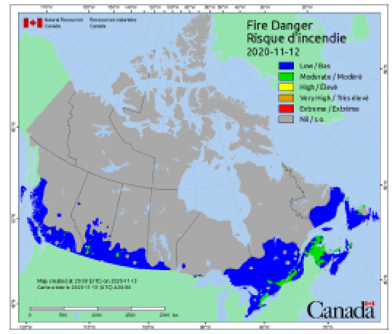
Another national portal on wildfire information is AirNow Fire and Smoke that provides a current interactive map of active fire location, smoke density, and AQI (air quality index) by site [27]. This resource combines three key components of fire and smoke data as seen in Fig. 3. The AirNow map utilizes multiple marks and channels to communicate location conditions. To encode AQI, and monitor type, AirNow uses different colored marks to indicate the AQI and shape of mark to indicate whether the AQI monitor is permanent, temporary, or low-cost. The smoke plumes are shown as an area mark of varying luminance to show smoke density over a particular geographical area. Lastly, shape marks are used to show the location and size of a fire. Other geographical locations have similar maps that provide AQI information. For example, an Australian AQI map called MyFireWatch shows a map with only AQI reports and location of sites [2].

In addition to the data visualized by AirNow Fire and Smoke and CWFIS, fire perimeters also provide necessary information for people who may be asked to evacuate an area or monitor how close they are to an active fire. Current fire perimeter maps exist, like the one provided by the BC Wildfire Service from the British Columbia Data Catalogue [12] shown in Fig. 4. This map communicates how big a fire is through a spatial representation (in total hectares) using area marks over a geographical map. This map is unique as it allows users to visualize overlayed BC data made available by the British Columbia Data Catalogue. Similar implementations of a perimeter map have been made such as Cal Gov's perimeter map that shows fire perimeters and their containment status on fires within the state of California [25]. Additionally there have been reports of Google implementing a fire perimeter map as a part of their Google Maps application, providing even more resource for emergency data [17].

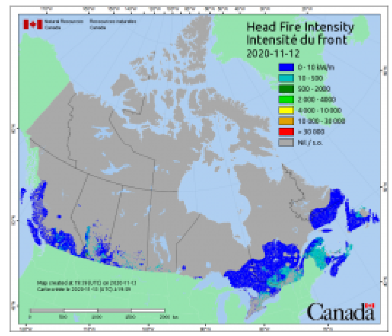
FireSmoke Canada [3] is another interactive visualization we came across which shows forecast of wildfires and smoke areas. They use hourly updated meteorological forecast for their predictive models. Their visualization is particularly interesting as by default it sums up fires in a region which makes it visually appealing; user can interact with the tool to get detailed information. Users can also see the movement of smoke clouds over geographical surface as an animation.

2.3 Academic Research in Wildfire Visualization

Academic researchers have extensively worked on formulating effective visualization for wildfire and related parameters. One tool worth mentioning is the Firemap [16], developed by WIFIRE Lab researchers, at the University of California, San Diego. The Firemap provides access to information on several different data sources, including historical fire



(a) Weather



(b) Fire Behavior

(c) Fire Hotspots

Fig. 2: Types of maps available in the Canadian Wildland Fire Information System (CWFIS). Left: Fire weather map.

information, fire perimeters, smoke, weather conditions, and real-time fire forecasting. Although the tool encompasses many of the concepts suggested for the solution in this proposal, the data displayed is limited to United States territory. Fig. 6 exemplifies Firemap's interface.

Another interesting avenue in wildfire visualization is presenting information in 3D and immersive environments [15, 19, 23]. These approaches are beyond the scope of our work but worth mentioning.

2.4 Animation

San Diego State University has also explored areas of fire animations which help communicate historical burned areas per year in their Web Based Mapping Services for the 2003 San Diego Wildfires [20]. Their approach employs animating the spread of fires as well by using point marks of varying saturation to communicate how the fire has spread and the activity overall.

The National Aeronautics and Space Administration (NASA) Earth Observatory explores animation of air quality data from March 2000 to August 2020 [1]. Their visualization displays one visualization of animated fire area marks over a geographical world map. This animation on its own is a sequence of daily frames over time with the ability of pausing or scrubbing through the timeline. There is a side menu that provides alternative particulates and satellite map visualizations to compare the fire shown in Figure 5. When any of these map views

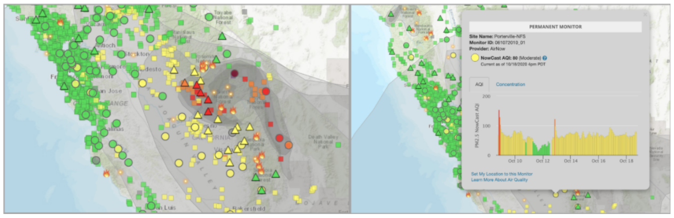


Fig. 3: AirNow Fire and Smoke interactive map. Left: view of the smoke density, fire location, and AQI. Right: by clicking one of the AQI sites, an information box provides relevant information to that particular AQI site location.

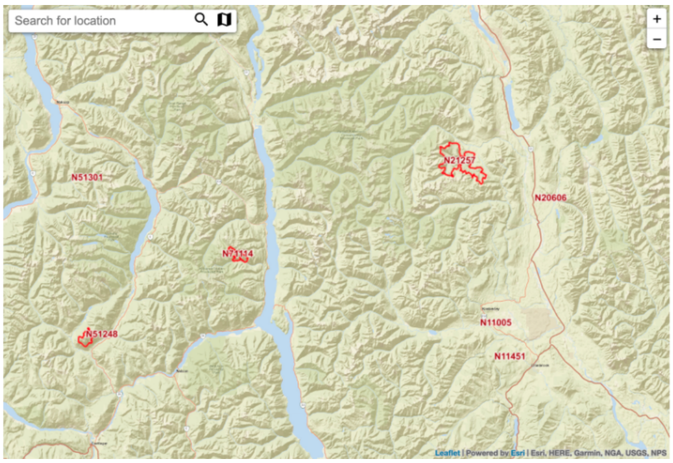


Fig. 4: Current fire perimeters outlined in red and provided by BC Wildfire Service on the BC Data Catalogue [12]. Fires are coded with their fire number in red text.

are clicked to compare, the fire map is juxtaposed to the selected vis. A description below the maps is available to communicate the impact of this particulate on the earth and the potential risks or changes fires contributed to the climate. The frames of the two juxtaposed visualizations are adjoined by time, thus the correlation between fire and the selected climate visualization is communicated through synchronized changes in both animations.

3 Domain Background

Wildfire data is collected by fire management agencies of different provinces in Canada which is compiled together as National Wild Fire Databases. As we have observed from browsing data sources from several province, there is subtle variation in data frame and types of information collected, for e.g., notations used to denote the fire class and burn code. However, the general focus is consistent which includes information about fire perimeters, cause of fire, time when the fire was started, areas affected, and geo-spatial location.

According to government data spread across national and regional levels, wildfires have an associated area burned. This area is often measured in hectares. For the purpose of this project, we maintain this notion where fires that cause a burned area of 200 hectares or more are considered large fires. As described previously, wildfires have an adverse affect on air quality. Air quality is quantified using the air quality index which is further calculated by the amount of particulates such as PM 2.5, PM 10, etc. We will update this section further when we use the air quality data into our visualization.

Over the course of various datasets we use, despite the subtle variations mentioned before, the details of wildfires are provided by their respective source agencies. These source agencies are usually divided by area and geographic location. The source agencies considered in this project, identified through used datasets, include agencies by provinces in Canada, territorial agencies and agencies that are managed by Parks

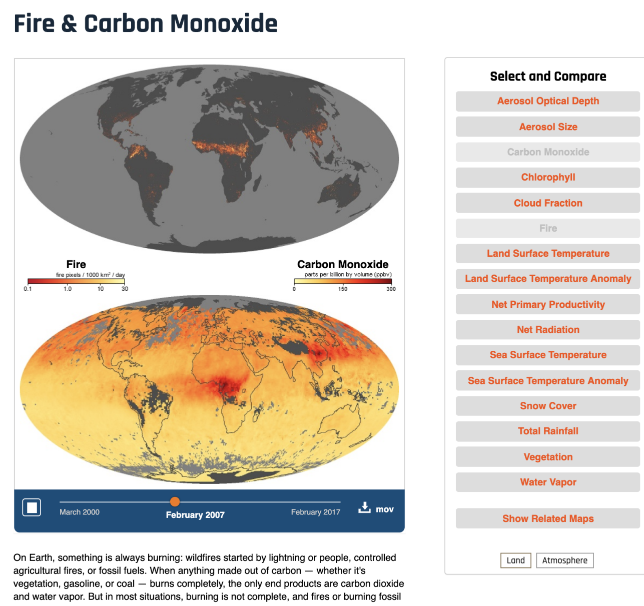


Fig. 5: NASA's Fire Observatory shows an animation of area marks for fires over a geographical map. Right hand menu shows possible comparisons for juxtaposition, all adjoined by time. Timeline allows the user to pause or scrub through to compare different correlations of the fire visualization.

Canada. We frequently categorize and organize our analysis based on these source agencies, and we use 'source agency' or simply 'region' when referring to these multiple types of sources. Primarily, we use data from the provinces, territories and parks: Alberta (AB), British Columbia (BC), Manitoba (MB), Nova Scotia (NS), Northwest Territories (NWT), Ontario (ON), Prince Edward Island (PEI), Parks (PC), Quebec (QC), Saskatchewan (SK), Yukon (YT), Newfoundland and Labrador (NL) and New Brunswick (NB).

4 Data

4.1 Data Sources

We have identified several Canadian data sources for wildfires, air quality index, and aspects that are impacted by wildfires, for example, property losses and government fundings. As per our task we require two types of data sets - tabular and spatial. Tabular data will help us analyze relevant attributes whereas spatial data will assist us to plot geo-tagged items. We have accessed data that include shape files to

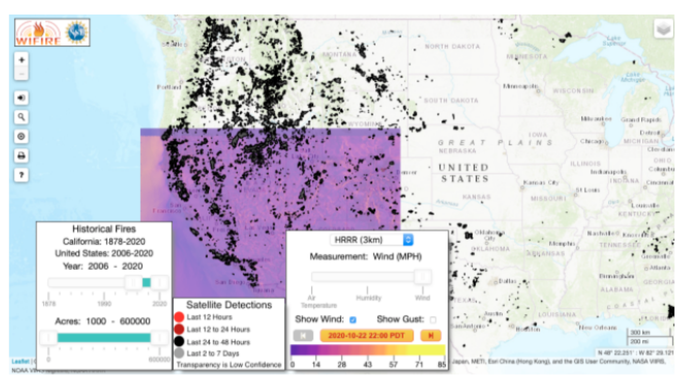


Fig. 6: Different views provided by Firemap [16], designed by researchers at the University of California, San Diego. Historical fires are coded in black, while the weather forecast is represented in the highlighted square region.

plot the exact regions of fires on a map chart. This is particularly useful for the current dashboard. Tabular data that we acquired can be used as it as or manipulated for obtaining derived attributes as needed. The attributes in tabular data are mostly categorical or ordered. Currently we are only scoping for a static data set with a particular range of years. Most historic data is available from the year 1930 to 2019, while there are variations according to data collection by government agencies. We have also recognized ways to obtain the most recent and current hourly data by importing it in real time. We discuss the 'What' aspect of each data source in the following subsections.

We collected data sources for information on current and historical wildfires, weather, climate, and air quality index data. Both shape files and csv files are available. Although the data for weather [6], climate [5] and air quality index [8, 9] are scattered based on the data sampling stations and need to be accumulated. We only found csv files for these data sources. We will be sampling these data resources in the coming weeks. We are also looking at the economic impact of wildfires and found historical data of the amount spent on handling wildfires over the course of years [14]. Exploring and analyzing the economic impact and the effect on temperature is one of the next steps we will perform. At this point, we have described in our report data sets that we have used to create our updated dashboards. We will include more data sources as we use them.

4.2 What: Data Abstraction

For the following data sources that we include, we first specify the technical details and structure of the dataset and then provide the abstracted 'What' summary for all data. However, this summary also points to the domain specific tabular description of the attributes in the data types abstraction, for making all details about data available in a single place.

4.3 Wildfire point data

Canadian Wildland Fire Information System, Natural Resources Canada [11] provides access to the data in the Canadian National Fire Database (CNFDB). One of these data sets is called the NFDB Agency Point data which contains information about all wildfire points that have occurred since the year 1930. This data consists of 413151 rows, each belonging to one Fire ID. The actual data has 27 attributes providing details about the location, date, expanse of the fire. Not all attribute values are available for each fire. We extracted the most relevant attributes, limiting the number of attributes used to 12 attributes.

'What?' Summary

- Data Types: Items and attributes. The attribute types include both categorical and ordered. Domain specific description - Each item corresponds to one fire ID. The names, data-specific descriptions and the type of each attribute is provided in Table 1.
- Dataset Type: Table
- Dataset availability: Static

Use in Dashboard: Historical

Table 1: Attributes and their descriptions: Wildfire point data

Attribute Name	Description and Data Type	Attribute Type
FID	Internal feature number. Sequential unique whole numbers that are automatically generated. Object identifier.	Categorical
Src Agency	The Source Agency (province, territory, parks) from which the fire data has been obtained. String.	Categorical
Fire Id	Agency fire ID. String.	Categorical
Latitude	Latitude. Double.	Ordered (Quantitative)
Longitude	Longitude. Double.	Ordered (Quantitative)
Year	Year of fire as provided by individual agencies. Integer.	Ordered (Ordinal)
Month	Month of fire as provided by individual agencies. Integer.	Ordered (Ordinal)
Day	Day of fire as provided by individual agencies. Integer.	Ordered (Ordinal)
Decade	Decade. String. Hierarchical.	Categorical
Size Ha	Fire size (hectares) as reported by the agency. Double.	Ordered (Quantitative)
Cause	Cause of fire as reported by the agency. String. 5 Possible Values: U(Unknown), L(Lightning caused fire), H(Human caused fire), H-PB(Prescribed burn human caused), Re(Reburn)	Categorical
More Info	Additional attributes provided by the agency. String.	Categorical (descriptive)

4.4 Yearly summary data

The point data described above has associated yearly summarized information. This dataset provides summary statistics derived from National Fire Database (NFDB) Agency Point data. This summary is available at both national and provincial or territorial levels.

4.4.1 National level summary

The national level data provides yearly aggregates of wildfire information of number of fires, total area burned, and these values for large fires (greater than 200 hectares), and the size of the largest fire in a given year.

'What?' Summary

- Data Types: Items and attributes. This data consists of attributes of type ordered. Domain specific description - Each item corresponds to one year of data. The names, data-specific descriptions and the type of each attribute is provided in Table 2.
- Dataset Type: Table
- Dataset availability: Static

Use in Dashboard: Historical

4.4.2 Regional level summary

Another version provides a sheet for each province, where each row corresponds to a year of data (1959-2019). For ease of joining this summarized information with the detailed agency point data, we adapted these multiple sheets of data into a single data sheet. Doing so, the data now has 61 rows (one for each year) for every source agency (province or territory). We thus created a column called SRC AGENCY to reflect the source agency of the fire. In addition to the attributes in Table 2, this data also provides the size of the smallest area burned in a given year. These two additional attributes are described in Table 3. The data thus comprises of 793 rows (61 year span x 13 source agencies) and 8 attributes.

'What?' Summary

- Data Types: Items and attributes. The attribute types include both categorical and ordered. Domain specific description - Each item corresponds to one year of data, for a given source agency. The list of names, data-specific descriptions and the type of attributes can be found in Table 2 and Table 3.
- Dataset Type: Table
- Dataset availability: Static

Use in Dashboard: Historical

Table 2: Attributes and their descriptions: Yearly summary data - National level summary

Attribute Name	Description	Attribute Type
YEAR	Year of fire	Ordered (Ordinal)
FIRES	Number of fires	Ordered (Quantitative)
TOTAL_HA	Area burned due to fires	Ordered (Quantitative)
MAX_SIZE_HA	Maximum size of fire in hectares	Ordered (Quantitative)
FIRES>200ha	Number of large fires	Ordered (Quantitative)
TOTAL_HA(>200ha)	Area burned due to large fires	Ordered (Quantitative)

Table 3: Additional Attributes and their descriptions: Yearly summary data - Regional level summary (Adapted data)

Attribute Name	Description	Attribute Type
MIN_SIZE_HA	Minimum size of fire in hectares	Ordered (Quantitative)
SRC AGENCY	Province / source agency / territory. 13 possible values (AB, BC, MB, NS, NWT, ON, PEI, PC, QC, SK, YT, NL, NB)	Categorical

4.5 Adjusted and homogenized Canadian climate data

The Adjusted and Homogenized Canadian Climate Data (AHCCD) [7] are datasets of climate stations that integrate modifications to historical station data (derived from statistical procedures) accounting for discontinuities from non-climatic causes, such as changes in instruments or relocation of stations. The dataset provides information on temperature, precipitation, pressure, and wind speed, together with station trend data, where available. The data contains 249,252 monthly records ranging from 1874 to 2019. Table 4 presents data-specific descriptions and the type of attributes.

'What?' Summary

- Data Types: Items and attributes. This data consists of attributes of type ordered. Domain specific description - Each item corresponds to homogenized climate data for a period of measurements. The names, data-specific descriptions and the type of each attribute is provided in Table 4.
- Dataset Type: Table
- Dataset availability: Static

Use in Dashboard: Historical

4.6 National Air Pollution Surveillance: Data-Donnees

The National Air Pollution Surveillance (NAPS) program [4], which began in 1969, is comprised of nearly 260 stations in 150 rural and urban communities reporting to the Canada-Wide Air Quality Database. It is considered the main source of ambient air quality data in Canada, gathering continuous and integrated measurements of key air pollutants. Continuous data are collected using gas and particulate monitors, with data reported every hour of the year, and are available as hourly concentrations or annual averages. Continuously monitored air pollutants are posted on an annual basis and include the following chemical species:

- carbon monoxide (CO)
- nitrogen dioxide (NO2)
- nitric oxide (NO)
- nitrogen oxides (NOX)
- ozone (O3)
- sulphur dioxide (SO2)
- particulate matter less than or equal to 2.5 (PM2.5) and 10 micrometres (PM10)

Table 4: Attributes and their descriptions: AHCCD

Attribute Name	Description	Attribute Type
lat	Latitude	Ordered (Quantitative)
long	Longitude	Ordered (Quantitative)
period_value	Period of measurement	Categorical
period_group	Periodicity group (monthly, annualy, daily)	Categorical
province__province	Province	Categorical
date	Start date of measurements	Ordered (Ordinal)
temp_mean	Mean temperature (C)	Ordered (Quantitative)
temp_mean_units	Mean temperature unit	Categorical
temp_max	Maximum temperature (C)	Ordered (Quantitative)
temp_max_units	Maximum temperature unit	Categorical
temp_min	Maximum temperature (C)	Ordered (Quantitative)
temp_min_units	Mean temperature unit	Categorical
total_precip	Total precipitation (mm/period)	Ordered (Quantitative)
total_precip_units	Total precipitation unit	Categorical
rain	Rainfall (mm/period)	Ordered (Quantitative)
rain_units	Rainfall unit	Categorical
snow__neige	Snowfall (mm/period)	Ordered (Quantitative)
snow_units	Snowfall unit	Categorical
pressure_sea_level	Sea level pressure (Pa)	Ordered (Quantitative)
pressure_sea_level_units	Sea level pressure unit	Categorical
pressure_station	Station level pressure (Pa)	Ordered (Quantitative)
pressure_station_units	Station level pressure unit	Categorical
wind_speed	Wind speed (m/s)	Ordered (Quantitative)
wind_speed_units	Wind speed unit	Categorical

Select sites also collect integrated samples over a 24-hour period every six days, which then are analyzed by the NAPS laboratory for additional pollutants. The dataset for samples collected on a time-integrated basis are posted on a quartely schedule and contain measurements on the following chemical species:

- fine (PM2.5) and coarse (PM10-2.5) particulate composition (e.g., metals, ions)
- semi-volatile organic compounds
- volatile organic compounds

Records range from 1974 to 2018 and are available at the Data-Donnees repository[1]. Since this data is not available in a compiled form, we utilized Python's webcrawling framework Scrapy [21] to gather all files locally. Further analysis of this source will be performed after the project update round, to be included in the historical tab.

4.7 BC Data Catalogue: Unverified Raw Current Hour Air Quality Data

The data provided from the BC Data Catalogue provides current hour Air Quality Health Index (AQHI) and particulate information by monitoring station. This is very similar to the historical data provided in Section 4.6. The current hourly data is exclusive to British Columbia and provides 106 particulate monitoring stations and 26 AQHI readings across the major areas of BC. The data is continuous and updated with the reports given from the stations, there are cases in which data points are missing if the station does not have the resources to monitor particulates for example. The dataset intends to provide current air quality

[1] http://data.ec.gc.ca/data/air/monitor/national-air-pollution-surveillance-naps-program/Data-Donnees/?lang=en

Table 5: Attributes and their descriptions: BC Data Catalogue Wind

Attribute Name	Description	Attribute Type
WDIR_VEC	Wind Direction Vector	Ordered (Ordinal)
WDIR_UNIT	Wind Direction Unit	Categorical
WDSD_VEC	Wind Speed Vector	Ordered (Ordinal)
WDSD_UNIT	Wind Speed Unit	Categorical

Table 6: Attributes and their descriptions: BC Data Catalogue Fire Perimeters Current

Attribute Name	Description	Attribute Type
FIRE_YEAR	year of fire as provided by individual agencies	Ordered (Ordinal)
SIZE_HA	area within the outside perimeter of the incident, in hectares	Ordered (Quantitative)
SOURCE	method used to create the spatial data for load into the datastore	Categorical
FIRE_STAT	control stage of the fire as of the last update, e.g, Under Control, Out of Control, Being Held, Out	Categorical

and meteorological data in raw format to the public, but is unverified by external sources as it is live data. The data also excludes Fraser Valley and Metro Vancouver air quality readings, though neighboring regions are close by. Air quality and monitoring stations are tracked to the nearest hour in Pacific Standard Time. Dataset also includes meteorological data which we will not be using in this implementation. Continuous air pollutants are posted hourly and include the following particulates:

- Carbon monoxide (CO) in parts per million (ppm)
- Hydrogen sulfide (H2S) and Total reduced sulfur (TRS) in ppb
- Nitric oxide (NO) in parts per billion (ppb)
- Nitrogen dioxide (NO2) in ppb
- Sulfur dioxide (SO2) in ppb
- Ground-level ozone (O3) in ppb
- PM2.5 (particulate matter with diameter of 2.5 micrometres or less) in micrograms per cubic metre (ug/m3)
- PM10 (particulate matter with diameter of 10 micrometres or less) in ug/m3

This dataset also provides wind direction and wind speed which we will use to evaluate our smoke data, since smoke and AQHI are closely related. This data is indicated in Table 5.

4.8 BC Data Catalogue: Fire Perimeters - Current

BC Data Catalogue also provides updated fire perimeters. These are wildfires that are active and inactive, supplied from multiple sources. The data is refreshed daily and are used to supply the BC Data Catalogue's Historical Fire Polygons each year. The Data Catalogue also provides a disclaimer claiming that fires are dynamic and can be fast growing, thus status may not be immediately reflected in the dataset. This is important to note for this fire data, as it should not be totally and completely relied on. Table 6 shows the data-specific descriptions and types of attribute.

5 Task Abstraction

On a higher-level, Firest should provide an overview of wildfires for general audience. We foresee it as a one-stop shop for any details related to wildfires. At the middle-level, it should allow user to explore a specific region of interest, for e.g, a resident of BC checking the active fires near Kelowna. At the low-level, there should be functionalities to identify a particular region of interests, compare it with some others or look for answers to specific questions related to wildfires, for e.g., which months observe highest number of forest fires in Canada?. We imagine our resulting visualization to be in the middle grounds where the user will have some flexibility to explore within the tool but the listed choices will be curated by the designers.

5.1 Actions

5.1.1 Analyze

Firest is specifically designed to consume curated information on wild fires. Target users can explore the up-to-date information about wildfire locations, their perimeters, weather data on the current tab and analyze trends of the previous years in the historical tab. Our end users can include general audience exploring wildfires in Canada, local residents checking evacuation areas, campers finding a suitable location having low wildfire risk, and tourists making plans depending upon air quality and visibility in an area.

5.1.2 Search

We propose to include filters which will enable users to lookup particular regions of interest. By browsing through a list of available options, interactivity will be provided to look at specific factors of analysis, specific locations etc.

5.1.3 Query

Identify: By looking at the map, users will be able to identify where the most recent fires are located and also view the smoke levels over those regions.

Compare: For this scope we didn't aim to design pane by pane comparison but users have the flexibility to visually compare regions of importance using the interactive tool bar.

Summarize: Wildfire data is available in both summarized national level information and detailed individual fire levels. If users intend to consume information at high-level, visualization overview will be available as a default mode. If they want to look at details about a specific impact, detailed graphs will be provided upon interaction with idioms and feature selection using the menu.

5.2 Targets

5.2.1 Trends

Once we visualize all data, we may come across certain regions that reflect some trend in occurrence of wildfires, for e.g., annual trend of number of forest fires in Canada. We wish to bring out these trends and highlight them in visualization.

5.2.2 Attributes

Distribution: Several queries are answered well with distributions. We aim to use line charts, bar-plots and other distribution idioms to show specific information about wildfires.

Correlation: There may exist correlation in attributes like wildfires and temperature, dependency among regions, and relationships between the number of fires and area burned due to fires. One of the targets is to visualize these correlations and relationships which might be impactful in understanding the effects of wildfires.

5.2.3 Spatial Data

Shape: Analyzing the fire perimeter is important to know the extent of wildfire in a specific region. Spatial data can be also helpful for inquiring about active fire regions, evacuation zone, and areas affected by forest fire smoke.

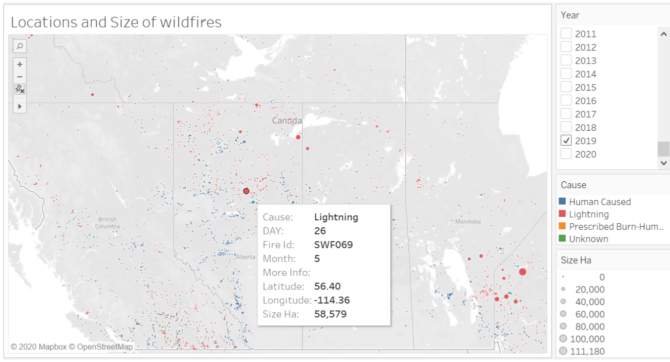


Fig. 7: Locations and Size of Fires (historical)

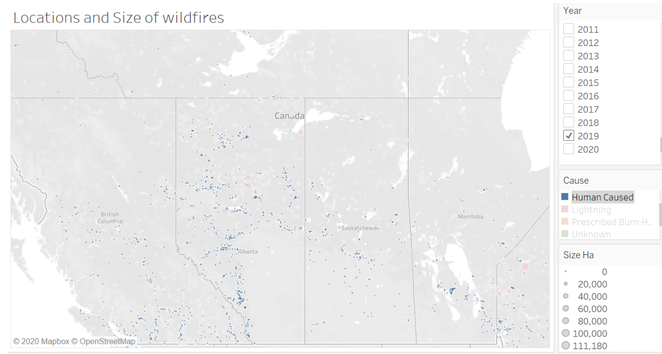


Fig. 8: Locations and Size of Fires (historical) : Highlighting a cause of fire

6 Solution and Analysis

Firest, our proposed wildfire visualization tool, provides a complete picture of the state of wildfires in Canada. Based on the discussed users needs, actions, and targets, our visualization aims to cater to the following: (1) Provide relevant real-time wildfire information in a single place through Current Tab, and (2) Analyze and present historically available data through Historical Tab.

For the current view, the data visualization will encompass air quality parameters, fire perimeter, and climate data related to wildfires. The historical tab will show the results gathered from analysis of various historical data sets covering wildfire points directly, economic aspects of wildfires, summarized high level view of wildfires and any inherent trends over the course of years. In this section, we will talk about various visualization idioms and discuss our design process and choices in detail.

6.1 Historical Tab: Visualizations and Design Choices

The overview of how the historical tab looks is shown in Fig. 1a. Individual components of the dashboard, including interactive maps and charts are described below.

6.1.1 Location and Size of Fires

Using the wildfire point data, we plotted the locations of wildfires using the latitude and longitude attribute values associated with each fire point. We use a scatter plot on a map chart to plot the wildfires as shown in Fig. 7. The horizontal axis plots the latitude and the vertical axis plots the longitude values. Here, both longitude and latitude are quantitative attributes.

In addition to this basic scatter-plot map chart, we encode the categorical attribute cause of the fire using the color channel. We also include a way to filter the ordinal attribute year using a multiple values list. The quantitative attribute size has been aggregated into seven levels so that the size of a point in the scatter-plot reflects the size of the fire.

Marks and Channels

- Circle encodes a wildfire point (a Fire ID)
- Color encodes the cause of fire
- Size of the circle encodes the size of the fire in hectares
- Tooltip provides more information about the wildfire point when hovered over a particular point. Details include: Fire ID, day, month, latitude, longitude, exact size in hectares and more information about the wildfire, if any.

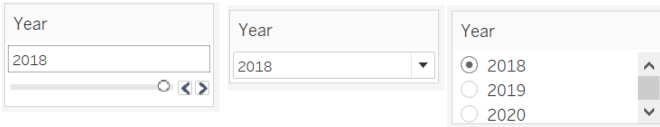
Filters and Interactivity

- A multiple value list filter is used to provide interactivity for selecting the year of fires to be shown.
- Manipulating Views
  - Highlighting a cause in the color legend shows wildfires caused only by those type. As shown in Fig. 8, when ‘Human caused’ is highlighted, a set of fire points with selected cause is shown while all other points are faded.
  - We used the navigation design choice that provides zoom in and zoom out functionality in the map, allowing to focus on a specific region as required. The user can also move around on the map using pan tool that lets the user see different areas of the map. Panning is especially useful when the map is in a zoomed view.
  - We intended to use the rule of ‘Overview First, Zoom and Filter, Details on Demand’ [22]. We provide an overview of wildfire points plotted on the map first then according to user needs, years can be filtered, details about fires using tool-tip can be viewed, and the map itself can be zoomed in and out.
- Design choices considered
  - Particular to filters provided, we had included a filter for selecting the province. However this filter is not very effective as the user can pan the map to a specific province they want to see. Viewing the province visually on the map rather selecting it in a drop-down list appears to be a more aesthetic choice.
  - For the filter ‘Year’, we considered multiple options available as shown in Fig. 9. We provided the option for selecting several years at a time if they want to see data over a range of years. We find providing a list is more intuitive than a drop-down in this case. We use this when we display a single view map. However, while incorporating this map into a dashboard, we use the multiple drop-down option to avoid clutter.

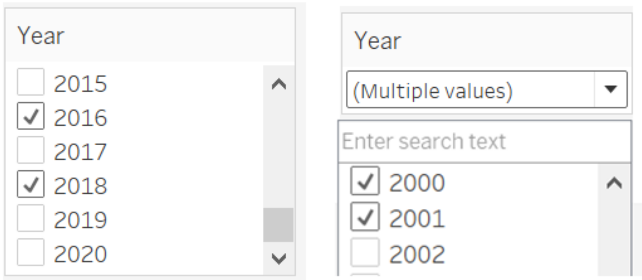
What-Why-How Summary

- Idiom - Geographic Map Chart.
- What: Data - Table: the two quantitative value attributes, Latitude and Longitude. Additional interactivity data: Categorical attribute Cause. Ordered (ordinal) attribute, Year, which has discrete levels. Ordered (Quantitative) attribute, Size.
- How: Encode - Express values with horizontal and vertical spatial position and point (circle) marks. Encoding size of circle for differentiating between sizes.
- How: Manipulate - Navigation using zoom in and zoom out functionality in the map, and the pan tool to see different areas of the map.
- How: Reduce - Filter by choosing out of the available discrete attribute values. Filter by highlighting specific categorical attribute values.
- Why: Task - Locate points. Find any extreme points.
- Scale - Items: Thousands for a given value of the ordinal attribute.

All what-why-how analyses have been adapted keeping [22] as reference.



(a) Options for selecting a single year. Left: Single value slider, Middle: Single value dropdown, Right: Single value list



(b) Options for selecting multiple years. Left: Multiple values list, Right: Multiple values dropdown (with search option)

Fig. 9: Design choices for the filter card ‘Year’

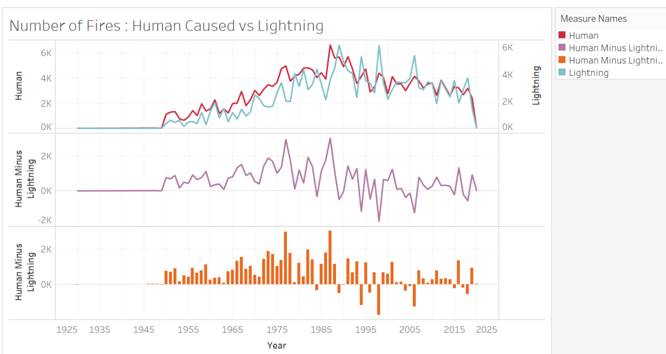


Fig. 10: Comparison of number of fires: human caused and lightning caused.

6.1.2 Fire Cause

Using the wildfire point data, we plotted the number of fires over the years, differentiated by the two most common causes: human and lightning (natural). We considered multiple design choices to reach the final chart as shown in Fig. 10. The horizontal axis plots the year and the vertical axis plots the number of fires. ‘Year’ is an ordinal attribute with discrete levels in this case and thus can be used to separate the horizontal space into discrete levels. We plot this graph to analyze if the number of fires caused by humans is more than the number of fires caused by lightning.

Marks and channels

- For the graph at top of Fig. 10:
  - Points connected by line connection marks encode the number of fires: human caused and lighting caused. There is one line for each type of cause.
  - Color encodes the cause of the fire.
- For the line graph in the middle of Fig. 10:
  - Points connected by line connection marks encode the difference between the number of human caused and lightning caused fires.
- For the bar graph at the bottom of Fig. 10:
  - Bar lines encode the difference between the number of human caused and lightning caused fires.
  - Length of bar encodes the magnitude.

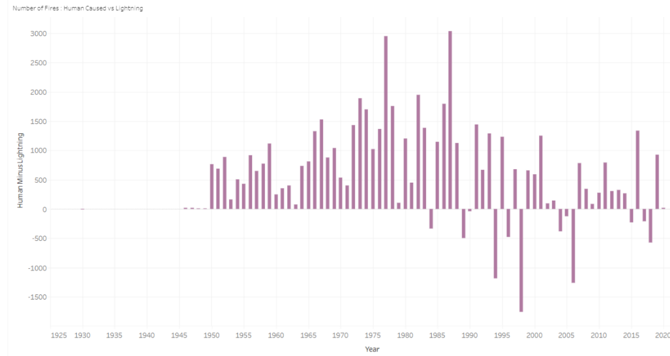


Fig. 11: Comparison of number of fires: human caused and lightning caused. Final choice is a bar chart.

Design choices considered

- We considered the three options presented in Fig. 10. Our final choice of chart is thus shown in Fig. 11. The attribute ‘Human minus Lightning’ was derived by subtracting the number of fires caused by lightning from the number of fires caused by humans, for each year. This newly created quantitative calculated field is then directly visually encoded as shown in Fig. 11. We made this decision keeping in mind that for tasks that require understanding this difference, Fig. 11 is preferable because it encodes the difference directly, enabling judgment of position along a common frame [22]. The chart at top of Fig. 10 puts a cognitive and perceptual load on the user, and is thus not preferred. Also, we preferred the bar graph over the line graph because we wanted to compare the two causes. Wherever the bar goes up, the difference is positive, meaning the number of fires caused by humans is greater than the number of fires caused by lightning, and vice-versa. Even though we might want to see it as a trend as shown in line graph, our aim of analysis here was to compare and lookup values.

What-Why-How Summary

- Idiom - Bar Chart.
- What: Data - Table: one quantitative attribute, Human minus Lightning, and one ordinal attribute, Year.
- How: Encode - Line marks, expresses quantitative value attribute with aligned vertical position, separate categorical attribute with horizontal position.
- Why:Task - Lookup and compare values.
- Scale - Ordinal attribute: less than a hundred discrete levels.

6.1.3 Wildfire Months

To determine the months in which occurrence of wildfires is most common, we plotted the count of number of fires over all years for each month. This is shown in Fig. 12, where the horizontal axis shows the months January(1) through December(12) while the vertical axis shows the count of fires. Here, Month is the ordinal attribute with 12 discrete levels while count of fires, i.e. count of Fire Id is quantitative.

Marks and channels

- Line mark (bar) encodes the count of fires.

Design choice We had an idea that most fires occur during spring through fall. However, to determine and to look up the exact numbers for any easy comparison of number of fires over the months called for the use of a bar chart.

What-Why-How Summary

- Idiom - Bar chart.

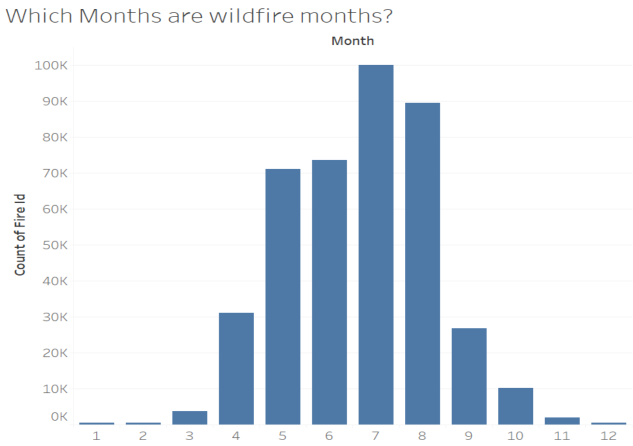


Fig. 12: Determining the wildfire months

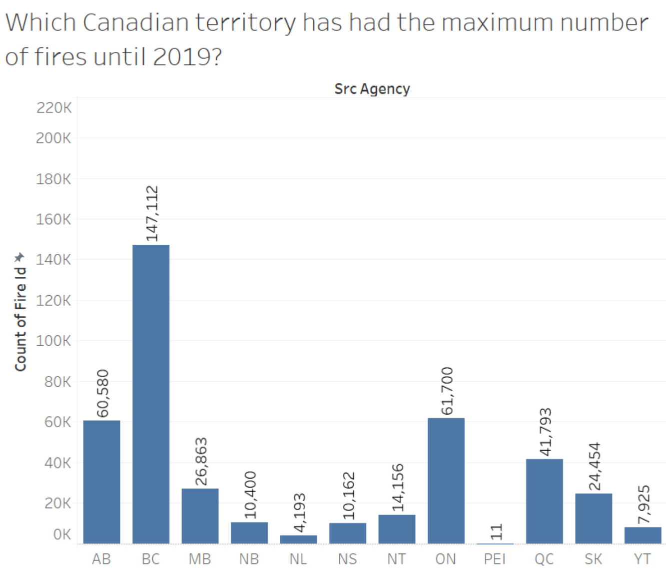


Fig. 13: Determining the region with largest number of fires

- What: Data - Table: one quantitative attribute, count of Fire Id, and one ordinal attribute, Month.
- How: Encode - Line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the ordinal attribute.
- Why: Task - Lookup and compare values of the quantitative attributes and how it varies over the discrete levels of the ordinal attribute. Look at the distribution of the quantitative attribute over the ordinal attribute.
- Scale - Ordinal attribute: a dozen levels.

6.1.4 Fires Within Each Region

To determine the regions with the largest number of wildfires, we plotted the count of number of fires, i.e., count of Fire Id, for each region. This is shown in Fig. 13, where the horizontal axis shows the regional source agency while the vertical axis shows the count of fires. The Src Agency (source agency) is the categorical attribute here, while the count of Fire Id is the quantitative attribute.

Marks and channels

- Line mark (bar) encodes the count of fires.
- Mark label to annotate the count of fires over the line bars.

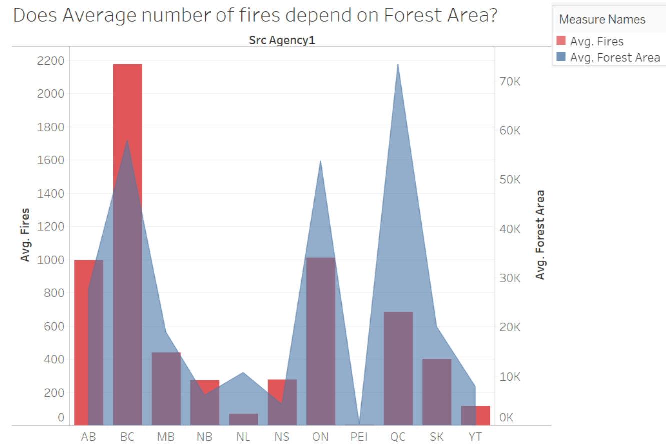


Fig. 14: Using area marks for forest area and line marks for average number of fires.

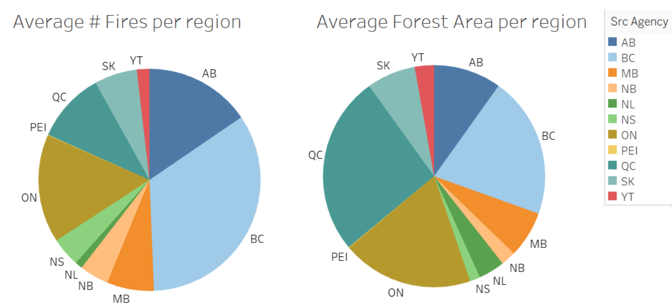


Fig. 15: Using a pie chart to represent forest area and average number of fires.

Design choice

- We chose a bar chart to represent this comparison as it is a straightforward and intuitive way to compare values over multiple categories. Since there were some regions with an extremely low number of fires like Prince Edward Island with only 11 fires as compared to British Columbia with 147,112 fires, we decided to annotate these values over the bars in the bar chart.

What-Why-How Summary

- Idiom - Bar chart.
- What: Data - Table: one quantitative attribute, count of Fire Id, and one categorical attribute, Src Agency.
- How: Encode - Line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the categorical attribute.
- Why: Task - Lookup to find the maximum value by comparing values of the quantitative attribute over the categorical attribute.
- Scale - Categorical attribute: a dozen levels.

6.1.5 Fire Count vs Forest Area

To determine if the average number of fires in a province or regions is dependent on the forest cover, we plotted the average number of fires over all the years for every region and the corresponding forest area for the region on the same graph. To differentiate the regions, we use the Src Agency (source agency) as the categorical attribute. The values we want to compare are quantitative attributes, number of Fires and Forest Area. Our final choice of graph is shown in Fig. 16, which are stacked bar charts.

Marks and channels

- For the graph in Fig. 14:

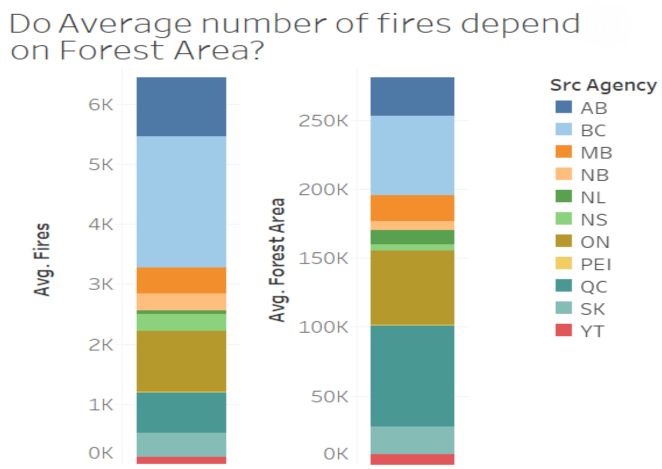


Fig. 16: Using a stacked bar charts to represent forest area and average number of fires.

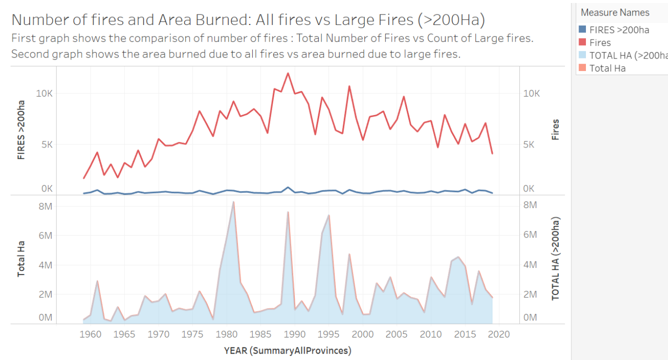
- Mark area encodes forest area.
- Mark line (bar) encodes average number of fires.
- Color encodes the attributes forest area and average number of fires, to differentiate between the two since shown on the same graph.

- For the pie graph in Fig. 15:
  - Proportional area / wedges with angle channel encodes the quantitative attribute average number of fires in the pie chart on the left of Fig. 15.
  - Proportional area / wedges with angle channel encodes the quantitative attribute forest area in the pie chart on the right of Fig. 15.
  - Color encodes the categorical attribute Src Agency (source agency).
- For the stacked bar graphs in Fig. 16:
  - Length inside the bar encodes the quantitative variable average number of fires for each category of the categorical variable Src Agency in the stacked bar chart on the left of Fig. 16.
  - Length inside the bar encodes the quantitative variable forest area for each category of the categorical variable Src Agency in the stacked bar chart on the right of Fig. 16.
  - Color encodes the categorical attribute Src Agency (source agency).

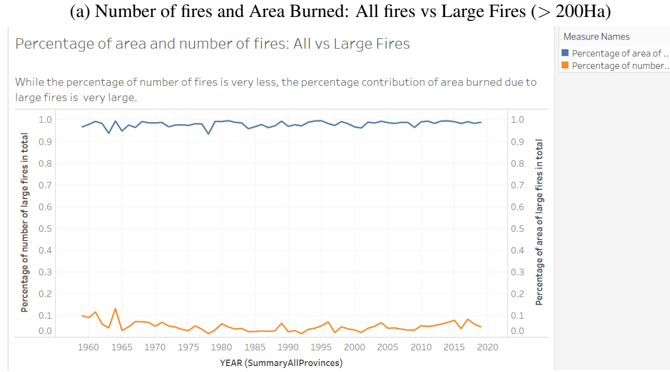
Design choices considered

- We considered the design choices presented in Fig. 14, Fig. 15 and Fig. 16.
- We preferred Fig. 16 over other choices as we find it the best option for comparing the proportion of average number of fires and the forest area for each region on the same frame, side by side. Thus, we use the two stacked bar charts, one for each of the quantitative attributes. We then place them side by side for ease of comparison.
- Fig. 14 is not preferred as it may represent a non-existent causality due to the the way the forest area is presented using area marks.
- Fig. 15 is not preferred as even though it represents the the proportion of area and number of fires, it puts a cognitive load on the user when viewing the visualization. It is not very easy to compare the values for a given region in determining if large areas correspond to the more number of fires or not.

What-Why-How Summary We use two separate stacked bar charts, one for each of the quantitative attributes in combination with the categorical variable. We thus combine the summary for both here.



(a) Number of fires and Area Burned: All fires vs Large Fires (> 200Ha)



(b) Percentage of area and number of fires: All vs Large Fires

Fig. 17: Design choices for comparing the number of fires and the total burned area

- Idiom - Stacked Bar charts.
- What: Data - Table: a quantitative attribute, average number of fires, and a categorical variable, Src Agency with 11 discrete levels.
- How: Encode - Bar with length inside the bar encodes the quantitative variable for each level of the categorical variable Src Agency in the stacked bar chart.
- Why: Task - Part-to-whole relationship. Compare the proportion of the quantitative variables for a given category over the two stacked bar charts (Lookup between two stacked bar graphs to find trends).
- Scale - Categorical attribute: eleven levels.

6.1.6 Fire Count vs Total Burned Area

Using the regional level summary data, we plotted the number of fires versus the total burned area over the years. We considered two design choices, shown in Fig. 17. In Fig. 17 (a), we juxtapose views of the count of fires (upper plot) and the total burned area in hectares (lower plot). The horizontal axis plots the year. Year is an ordinal attribute with discrete levels in this case and thus can be used to separate the horizontal space into discrete levels. The purpose of this plot is to analyze possible interactions between the number of fires and the size of the total burned area over the years. We plot these graphs to evaluate the contribution of all fires collectively and only large fires that cause a burned area of greater than ha. The contribution is quantified in terms of the number of fires and the the area burned.

Marks and channels

- For the graph at top of Fig. 17 (a):
  - Points connected by line connection marks encode the number of fires, which are categorized into fires of all sizes and fires that are greater than 200ha. There is one line for each type of cause.

- Color encodes the category of the fire (all fires or fires with burned areas greater than 200ha).

- For the area graph at the bottom of Fig. 17 (a):
    - Points connected by line connection marks encode the total burned area in hectares.
    - Area mark encodes the total burned area in hectares due to large fires (fires greater than 200ha).
- For the graph at Fig. 17 (b):
    - Points connected by line connection marks encode the percentage of the area burned by large fires.
    - Points connected by line connection marks encode the percentage of fires that were considered large fires ($>$ 200ha).
    - Color encodes area burned or count of large fires

Design choices considered

- We considered the design choices presented in Fig. 17.
- Fig. 17 (a) allows the comparison of both trends for large fires and for all fires. The area displayed in the bottom chart emphasizes the burned areas due to the large fires. Also, the juxtaposition of count of fires and area burned provides a more comprehensive context of the trend in fire occurrence over the years.
- The use of percentages in Fig. 17 (b) allows for a faster identification of trends over the years for the large fires. This graph supplements the information provided in Fig. 17 (a). It directly shoes that even though proportion of number of large fires in all fires is very small, the proportion of area burned due to large fires is very large. This information is also directed to the user using text annotation above the graph.

What-Why-How Summary

- Idiom - Line Chart.
- What: Data - Table: two quantitative attributes, count of fires and total burned area, one categorical attribute, all fires or fires bigger than 200ha, and one ordinal attribute, Year.
- What: Derived data: two quantitative attributes, percentage of fires that were considered large fires ($>$ 200ha) and percentage of total area burned due to large fires, one categorical attribute, and one ordinal attribute, Year.
- How: Encode - Line marks, expresses quantitative value attributes with aligned vertical position, separate categorical attribute with horizontal position.
- Why: Task - Lookup and compare values.
- Scale - Ordinal attribute: less than a hundred discrete levels.

6.1.7 Historical Trends

To understand the trend in occurrence of fires over the decades, we plotted the count of number of fires over all decades from 1930 to 2020, for each year. This is shown in Fig. 18, where the horizontal axis shows the decades 1930 through 2020 while the vertical axis shows the count of fires. Here, decade is the ordinal attribute with 10 discrete levels while count of fires, i.e. count of Fire Id is quantitative.

Marks and channels

- Line mark (bar) encodes the count of fires.

Design choices considered

- We had an idea that most fires occurred during the decades of 1980 and 1990. The number of fires seem to be decreasing since then, however, to get a full picture it is necessary to understand the total burned area.

What-Why-How Summary

- Idiom - Bar chart.
- What: Data - Table: one quantitative attribute, count of Fire Id, and one ordinal attribute, Year.

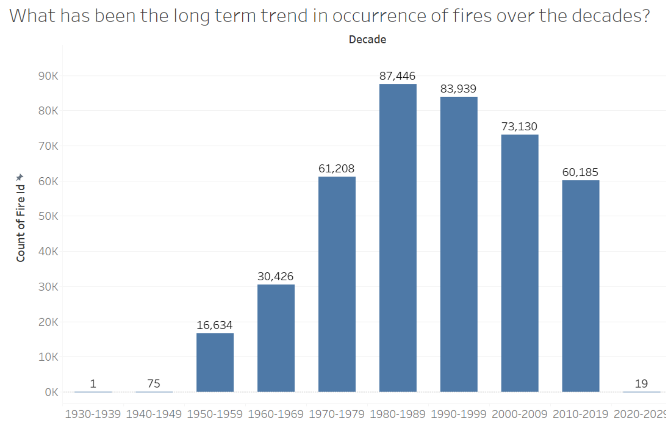


Fig. 18: Design choice for analysis of trends in occurrence of fires over the decades

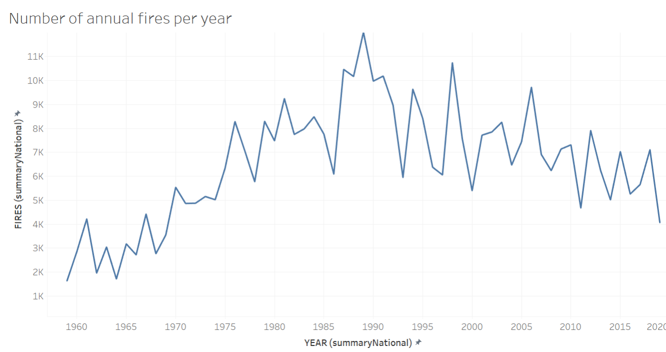


Fig. 19: Design choice for analysis of number of fires per year

- What: Derived - Table: one ordinal attribute, decade (binning of years with 10 items).
- How: Encode - Line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the ordinal attribute.
- Why: Task - Lookup and compare values of the quantitative attributes and how it varies over the discrete levels of the ordinal attribute. Look at the distribution of the quantitative attribute over the ordinal attribute.
- Scale - Ordinal attribute: ten levels.

6.1.8 Annual Forest Fire

To understand the trend in occurrence of fires over the years, we plotted the count of number of fires over the years from 1960 to 2020. This is shown in Fig. 19, where the horizontal axis shows the years 1965 through 2020, while the vertical axis shows the count of fires. Here, year is the ordinal attribute with 35 discrete levels while count of fires, i.e. count of Fire Id is quantitative.

Marks and channels

- Points connected by line connection marks encode the count of occurrence of fires.

Design choices considered

- We had an idea that most fires occurred during the years of 1985 and 1995. The number of fires seem to increase from 1960 to 1980, and decrease after year 2000. However, to get a full understanding of the trends it is necessary to look at the total burned area.

What-Why-How Summary

- Idiom - Line chart.

- What: Data - Table: one quantitative attribute, count of Fire Id, and one ordinal attribute, Year.
- How: Encode - Line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the ordinal attribute.
- Why: Task - Lookup and compare values of the quantitative attributes and how it varies over the discrete levels of the ordinal attribute. Look at the distribution of the quantitative attribute over the ordinal attribute.
- Scale - Ordinal attribute: ten levels.

6.2 Current Tab: Visualizations and Design Choices

We aim to focus on providing a detailed overview of current fire data within British Columbia shown in Fig. 1b. Data for other provinces is available, although this data is not cumulative of all of Canada and data format varies from province to province. We aim all of our visualizations for the current tab on British Columbia data. Similar to the historical tab, we intended to use the rule of 'Overview First, Zoom and Filter, Details on Demand' [22]. The overall design of this tab is a superimposed geographical map with multiple current fire data elements which will be described below.

6.2.1 AQHI

Detailed AQHI is used from available hourly data within BC.

Marks and Channels

- Circle encodes a air monitoring station location
- Color hue encodes the current AQHI reading from that station provided by the BC Data Catalogue hourly data
- Tooltip provides detailed information about the monitoring station's name, location, time updated, current and future AQHI readings, and a breakdown of particulates in the air: CO, NO, O3, PM10, PM2.5, and SO2.

Filters and Interactivity

- Users can hover over the colored circles marks to reveal the Tooltip details. We are exploring a couple ways to do this and what information is the most relevant. BC Data Catalogue provides a lot of information of each AQHI monitoring site and score shown in Fig. 20 and Fig. 1b.
- Shown in the top right of Fig. 21, we implement a legend for showing explaining the AQHI color. AQHI scores within Canada are scored out of 10 and air quality is indicated by a commonly transferable color coding: lower AQHI score is green, moderate is yellow, and red is not healthy to breathe for extended periods of time.
- Design choices considered
  - Organization of the tool-tip is one thing we considered. While we didn't want to overload the tool-tip with text, we also wanted to accomplish providing enough information to the user about the current AQHI reading. We are still considering what messages to include, but have decided health risk level and recommendation for activity outdoors. While considering these factors, we have decided that things like time and date updated, station name and AQHI reading are top priority with explanations of particulates comes next. We have not implemented this organization yet, but aim to do so.
  - Color of the AQHI marks indicates level of health risk in the area. This is on a spectrum of green to yellow to red, but we considered a segmented color spectrum as well. This non linear color spectrum (Fig. 21 was chosen to show the possible in between AQHI readings that may happen. Because this is not very common in AQHI scores and there are not many AQHI values, we may go back to the segmented color spectrum as this is more common with British Columbia AQHI scales.

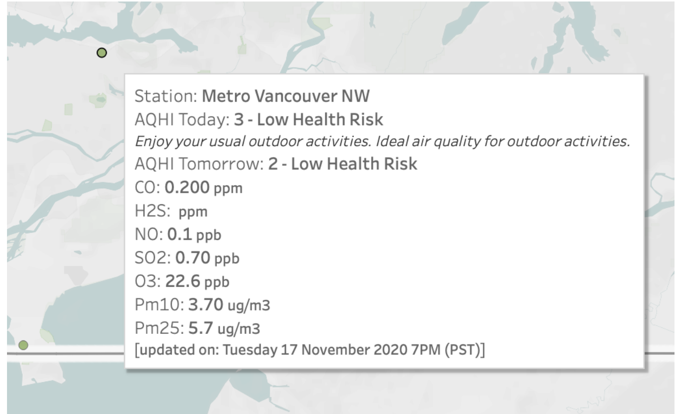


Fig. 20: Text based details on the tool-tip for the Current tab when users hover over a circle mark

Fig. 21: British Columbia's AQHI live data seeded from gov.bc.ca hourly AQHI data

What-Why-How Summary

- Idiom - Geographic map chart
- What: Data - table:
  - Categorical key attribute attribute: AQHI
  - Ordered key attribute: time
  - Categorical attribute: station name
  - Categorical attribute: particulate types (CO, NO, O3, PM10, PM2.5, SO2, H2S)
- How: Facet - clicking or hovering on a point marks expresses location of AQHI monitoring site.
- How: Encode - color expresses category of AQHI at the monitoring site on the map.
- Why: Task - Locate monitoring sites. Find values, name, time updated associated with different locations
- Scale: one reading per location with 13 or less items. Total of 106 particulate monitoring sites and 26 AQHI sites. We show only sites with AQHI and particulate readings.

6.2.2 Fire Perimeters

We also get the fire perimeter data from the exported .shp file from BC Data Catalogue. We currently are using static data, but working on making the data live.

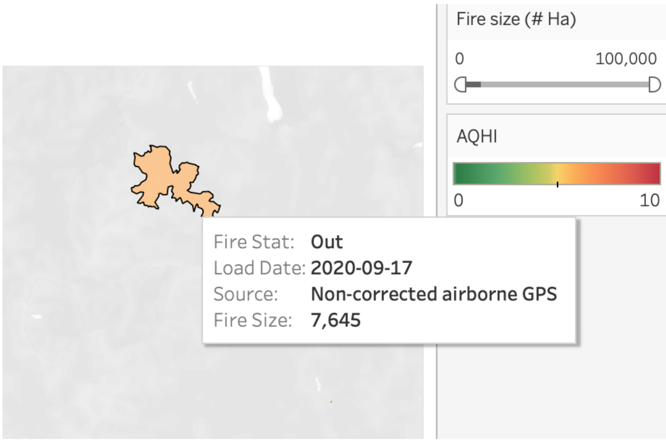


Fig. 22: Fire Perimeter is shown by the position of an area mark over the geographical map relative to its size in Hectares.

Marks and Channels

- Area mark encodes location and relative size (in Hectares) of fire over a geographical area
- Tooltip provides detailed information about the fire's size, approximate location, updated time, source of the report, and status of the fire.

Filters and Interactivity

- Users can hover over the different area marks to reveal the Tooltip details. We are exploring a couple ways to do this and what information is the most relevant. Currently we have considered fire status, latest date updated, source of report, and size to be the most prevalent information shown in Fig. 22.
- Visible fire perimeters can be filtered shown in the filter in the top right corner of Fig. 22. The user can select the range of viewable fires by size in Hectares.

Design choices considered

- We superimpose the fire perimeter area marks over the AQHI map to show fire size and proximity of monitoring sites. We wanted to show the closeness of monitoring sites to fires so users looking at air quality or fire size and status are able to correlate the two in one interactive map.
- We have decided to color the area marks one color to indicate where a fire is and its relative size to allow easy visibility and color contrast to the AQHI marks and map background. We considered also color filtering the fire status, but since we are also using color as a channel for AQHI, we do not want the map to be overly complex or visually confusing. We may reconsider this color to something that is not on the AQHI color encoding spectrum to be more distinct.
- We also plan on implementing a filter allow users to filter the viewable fires by the status of under control, out of control, being held, or out.

What-Why-How Summary

- Idiom: Cartographic layering
- What: Data - Geometry
  - Spatial position key attribute: fire area
- How: Encode - area marks for size of fire
- How: Facet - superimpose static layers of distinguished by a contrasting color of the map background. Clicking or hovering on a area mark expresses location and details of fire.
- Why: Locate fires and relative size
- Scale: one reading per location with 4 items, 0 or more fires depending on the conditions.

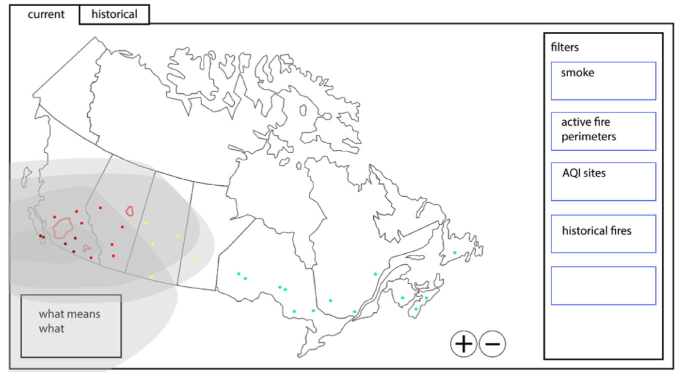


Fig. 23: Early mock-up of current tab from project proposal.

6.2.3 Smoke and Wind

This is a to-be-implemented section. We are including it in the project update to outline the way we plan on designing this facet of the current tab. Refer to Table 5 for the data we will be using for this section provided by the BC Data Catalogue.

Marks and channels

- Dynamic area mark encodes smoke coverage over a given geographic location
- Opacity encodes smoke density
- Animation encodes wind direction

Filters and Interactivity

- Toggle dynamic or static: Smoke and wind direction will be a dynamic feature by default, there will be a feature to toggle it off and for it to remain static. Static sketch is presented in Fig. 23.
- Toggle view: Smoke and wind direction may be overcrowding over a fiery area, filter of viewing and not viewing the smoke data will be possible with a on/off checkbox.
- Filter at the bottom of the dashboard will show the movement over the 24hr period, by default this will be a running timeline, though can be paused by the dynamic/static toggle.

Design choices considered

- Dynamic animated smoke can help show density as well as direction of the smoke. We hope to show this over landmarks such as highways in the geographical view. This will also be superimposed over the AQHI and fire perimeter maps.
- We chose to make opacity a channel in which users can easily correlate smoke density to real-life situations. This may be in one of two ways: the first design we are considering will be area marks of the same opacity so when they are superimposed, the overlapping area that looks darker will communicate denser smoke. Another consideration is to create a single area mark varying in opacity throughout the mark. This approach may be more suitable to animate, as we wont have to manipulate multiple area marks over one another.

What-Why-How Summary

- Idiom - Cartographic layering
- What: Data - Table:
  - Spatial position key attribute: smoke area
- How: Encode - area marks for size of smoke cover
- How: Facet - opacity expresses the density of smoke cover. Animation expresses the wind direction
- Why: Task - Locate areas that are affected by nearby fires as well as impacted areas over the last 24 hours.
- Scale - 0 or more smoke covered areas that are determined by available data and active fires.

7 IMPLEMENTATION

7.1 Data gathering and preprocessing

The data gathering is performed either by direct download of static files, web-scraping using Python's Scrapy, or dynamic scraping using Google Sheets and Tableau connectors. Preprocessing steps include mainly merging data from multiple provinces and stations, and are done using Python.

7.2 Visualization

We chose Tableau[2] as the primary tool for implementing our solution. Recent versions of Tableau offer support to geographical data, and are able to plot different types of spatial files. Also, the tool's functionalities for joining and creating relationships among multiple tables mitigates the problem of dealing with disjointed data sources, as discussed in Sect. 4. Furthermore, Tableau provides native functionalities for the creation of interactive dashboards, which are useful for displaying complex information. Last, once the project is completed, the visualization can be published in Tableau Public's gallery[3], allowing for easy distribution with the general public.

8 RESULTS

Firest would benefit a multitude of end users. The current tab would give data based on active fire information and the historical tab would help users compare historical fire and climate data. Here we list usage scenarios of possible end users.

Checking current fire forecasts. In one case, users may be coming to the Firest interactive map to check on the status of the area of a wildfire, smoke plume forecast, and AQI reading of a site close to their location. It is natural for a user to come here and compare how much a fire has grown after checking from a previous day and viewing whether their day may be impacted. It may be the case that this data visualization can help people in dire situations, providing unified emergency data and evacuation alerts and orders surrounding fires. Filters will allow the user to select what information they would like to view over the map, relevant to their outdoor activity or home safety.

Viewing current fires compared to historical fires. Another feature of the current tab will be viewing an superimposed map of historical fires over current fire perimeters. The user may come here to answer questions such as: Was there a fire here recently? Is this area I want to go backpacking burning or already burned? They will be able to use the filters to view the current and historical information superimposed, and not view the AQI or smoke.

Observing historical fire trends and climate impacts. In the historical tab users will come here to view more than just the geographical location and area of a historical fire. This tab will provide comparative information such as the number of fires per year compared to the area burned per year. By coming here users will be able to compare information that existing tools do not provide comparisons for. For example, a user will come to the historical page to view the causes of the past few years of wildfires, their location, change of atmospheric carbon dioxide, variation in temperature and air quality levels.

9 MILESTONES

The milestones were divided in a way that all team members have similar workloads. A breakdown of the tasks, estimated timeline, and the updated actual timeline of work done so far is shown in Table 7.

10 DISCUSSION AND FUTURE WORK

11 CONCLUSIONS

ACKNOWLEDGMENTS

REFERENCES

[1] Fire & aerosol optical depth.
[2] G. o. W. A. Australia. Myfirewatch - bushfire map information australia.
[3] B. Canada. Smoke map.
[4] E. Canada and C. C. Canada. National air pollution surveillance (naps) program. Available from the Government of Canada Open Data Portal at open.canada.ca.
[5] E. Canada and C. Change. Canadian historical weather radar - climate - environment and climate change canada, Oct 2011. Last Modified: 2020-09-17.
[6] E. Canada and C. Change. Historical data - climate - environment and climate change canada, Oct 2011. Last Modified: 2020-09-17.
[7] E. Canada and C. Change. Adjusted and homogenized canadian climate data (ahccd), Sep 2018. Last Modified: 2020-10-13T15:24:40Z.
[8] M. o. E. Canada. Current air quality data - province of british columbia. Last Modified: 2020-10-18.
[9] N. R. Canada. Air quality monitoring: Verified hourly data - validated hourly air quality and meteorological data - data catalogue.
[10] N. R. Canada. Canadian wildland fire information system.
[11] N. R. Canada. Canadian wildland fire information system — canadian national fire database (cnfdb).
[12] N. R. Canada. Fire perimeters - current - data catalogue.
[13] N. R. Canada. Climate change and fire, Jul 2013. Last Modified: 2020-07-07.
[14] N. R. Canada. Cost of wildland fire protection, Sep 2015. Last Modified: 2020-07-15.
[15] M. Castrillón, P. A. Jorge, I. J. López, A. Macías, D. Martín, R. J. Nebot, I. Sabbagh, F. Quintana, J. Sánchez, A. J. Sánchez, et al. Forecasting and visualization of wildfires in a 3d geographical information system. *Computers & geosciences*, 37(3):390–396, 2011.
[16] D. Crawl, J. Block, K. Lin, and I. Altintas. Firemap: A dynamic data-driven predictive wildfire modeling and visualization environment. *Procedia Computer Science*, 108:2230 – 2239, 2017. International Conference on Computational Science, ICCS 2017, 12-14 June 2017, Zurich, Switzerland. doi: 10.1016/j.procs.2017.05.174
[17] L. Goode and B. Ashworth. Google expands its fire-tracking tools—and just in time. *Wired*, 2020.
[18] M. Greenbelt, E. S. Data, I. S. Project, E. S. P. Division, F. P. Directorate, G. S. F. C. N. Aeronautics, and S. Administration. Earthdata search.
[19] R. V. Hoang, M. R. Sgambati, T. J. Brown, D. S. Coming, and F. C. Harris Jr. Vfire: Immersive wildfire simulation and visualization. *Computers & Graphics*, 34(6):655–664, 2010.
[20] H. D. Johnson. Web based mapping services for the 2003 san diego wildfires.
[21] D. Kouzis-Loukas. *Learning Scrapy*. Packt Publishing Ltd, 2016.
[22] T. Munzner. *Visualization Analysis and Design*. AK Peters Visualization Series. CRC Press, 2014.
[23] W. R. Sherman, M. A. Penick, S. Su, T. J. Brown, and F. C. Harris. Vrfire: an immersive visualization experience for wildfire spread analysis. In *2007 IEEE Virtual Reality Conference*, pp. 243–246. IEEE, 2007.
[24] Q. Sun, C. Miao, M. Hanel, A. G. L. Borthwick, Q. Duan, D. Ji, and H. Li. Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming. *Environment International*, 128:125–136, Jul 2019. doi: 10.1016/j.envint.2019.04.025
[25] C. D. o. F. USA and F. Protection. 2020 statewide fire summary — welcome to cal fire.
[26] C. f. D. C. USA and Prevention. Climate change and public health - health effects - wildfires, Jun 2020.
[27] E. P. A. USA. Fire and smoke map.

[2] https://www.tableau.com/
[3] https://public.tableau.com/en-us/gallery/

Table 7: Milestones and task breakdown.

Milestone Task Breakdown	**Estimated hours** (per person)	**Actual Hours** (per person)	**Estimated Completion Date**	**Actual Completion Date**	**Assignee**
Pitch					
Presentation	3	3	Oct 1	Oct 1	Everyone
Pre-proposal meeting					
Merging project topics, collecting data sources and preparing meeting agenda	3	3	Oct 13	Oct 13	Everyone
Meeting time	3	3	Oct 13	Oct 13	Everyone
Proposal					
Brainstorm solution, define data sources	2.5	2.5	Oct 22	Oct 22	Everyone
Report write-up	3	3	Oct 22	Oct 23	Everyone
Implementation					
Data sourcing and cleaning	7	9	Oct 30	Nov 8	Everyone
First draft of Current tab in Tableau (Design choices, Connecting data)	10	10	Nov 6	Nov 14	HE, PV
First draft of Historical tab in Tableau (Design choices, Analysis)	10	10	Nov 13	Nov 14	RC, RG
Update Report					
Writing and Modifying report per feedback	8	16	Nov 16	Nov 17	Everyone
Meeting Times	-	5.5	Frequent	Frequent	Everyone
Peer project report					
Read peer update report, prepare feedback	2		Nov 19		Everyone
Refine implementation from first draft					
Add charts for temperature, AQI, economy data	8		Nov 27		RC, RG
Add smoke data, real-time data, notifications	8		Nov 27		HE, PV
Merge views, design dashboard views	6		Dec 2		Everyone
Final Presentation					
Finalize demo, prepare and rehearse presentation	4		Dec 9		Everyone
Final Paper					
Finalize report	10		Dec 13		Everyone