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

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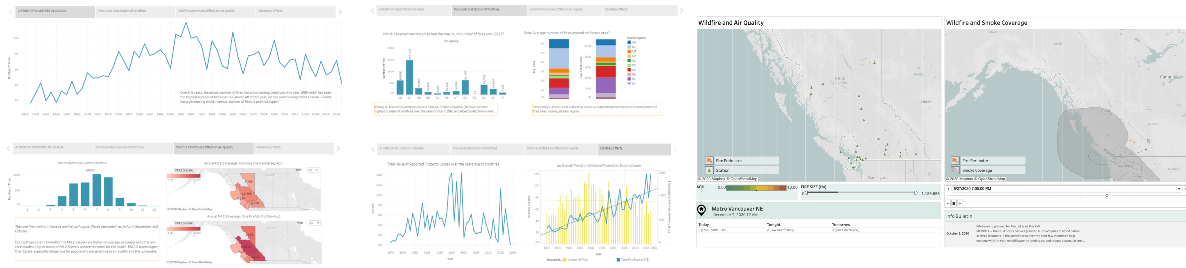

(a) Historical Tab

(b) Current Tab

Fig. 1: Sample 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 instance, air quality index, smoke map, weather patterns drawn from historical data. In this context, we present Firest — a Tableau-based visualization of current and historical wildfires; published on the web for open access. Firest aims to integrate multiple variables of interest regarding wildfires in one resource, 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 behavior of wild-land fires have varied dramatically over time and space, largely due to the dynamic consequences of climate change and climate instability [47]. Additionally, there are expected shifts in wildland 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 [41]. 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 [12]. 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 [31]. 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 neighborhoods.

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 [47], and vice-versa, creating a torrential climate change snowballing effect. We propose to centralize air quality, smoke plumes, active fires, and historical climate data to be viewed in a single dashboard.

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*Web interface available at: https://firest547.github.io/*

## 2 Related Work

There are several wildfire visualizations developed by governmental agencies [19, 24, 38], commercial corporations [4, 21], and researchers in academia [8, 13]. The techniques and approaches used for visualizing wildfires, related parameters, and other geographical data are of interest and discussed thoroughly in this section.

### 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 [38]. This resource provides various dataset, such as fire weather maps, fire behavior maps and fire 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 behavior 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. 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 [38]. 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. The Fire M3 hotspots map plots high infrared intensity satellite image pixels representing heat sources. A hotspot may correspond to one fire, or one of the many hotspots that reflect a larger fire. The representation of active fires is crucial to our dashboard and we incorporated active fire region and relevant regional warnings in our current view.

### 2.2 Visualization of Wildfire Related Parameters

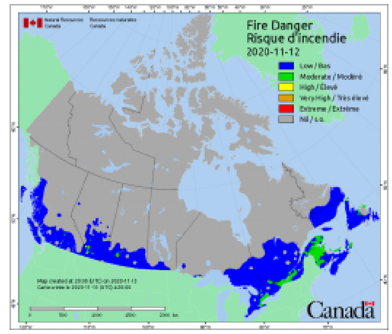
Another national portal on wildfire information is AirNow Fire and Smoke that provides a current interactive map of active fire location, smoke density, and AQI (air quality index) by site [19]. This resource combines three key components of fire and smoke data as seen in Fig. 3. The AirNow map utilizes multiple marks and channels to communicate location conditions. To encode AQI, and monitor type, AirNow uses different colored marks to indicate whether the AQI monitor is permanent, temporary, or low-cost. The smoke plumes that are smoke density over a particular geographical area are shown as area marks of varying luminance. 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 [24].

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 [40] 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. 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 [10]. Additionally, there have been reports of Google implementing a fire perimeter map as a part of Google Map, providing a consolidated resource for wildfire emergency data [22].

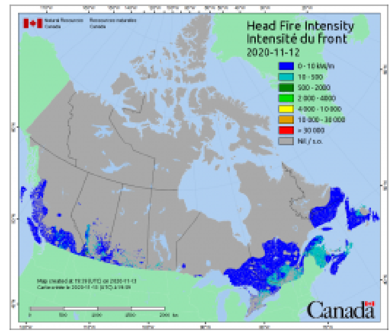
FireSmoke Canada [8] is another interactive visualization we came across which shows forecast of wildfires and smoke areas. They use hourly updated meteorological forecast for their predictive models. Their visualization is particularly interesting to us as by default it sums up fires in a region which 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

Academic researchers have extensively worked on formulating effective visualization for wildfire and related parameters. One tool worth mentioning is the Firemap [13], developed by WIFIRE Lab researchers, at the University of California, San Diego. Firemap provides access to information on several different data sources, including historical fire information, fire perimeters, smoke, weather conditions, and real-time fire forecasting. Fig. 5 exemplifies Firemap's interface. Although the




(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.

tool encompasses many of the concepts suggested for the solution in this proposal, the data displayed is limited to United States territory. Additionally, it only represents the current state of affairs. In our implementation we want to dive deep into the historical trends as well as show a bigger picture.

Another interesting avenue in wildfire visualization is presenting information in 3D and immersive environments [11, 26, 45]. These approaches are beyond the scope of our work but worth mentioning.

### 2.4 Interactive and Dynamic Visualizations

Static visualizations are overwhelming if several attributes are displayed together on the map. They are also monotonous and do not pave way for curiosity driven exploration. Interactivity is a crucial concept here. Treepedia [34], Global Diplomacy Index Dashboard [30], and America Panaroma Project [14–16] have several compelling interactive visualization based on geographical data.

San Diego State University has 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 [28]. Their approach employs animating the spread of fires by using point marks of varying saturation to communicate the spread of the fire and overall wildfire activity.

The National Aeronautics and Space Administration (NASA) Earth

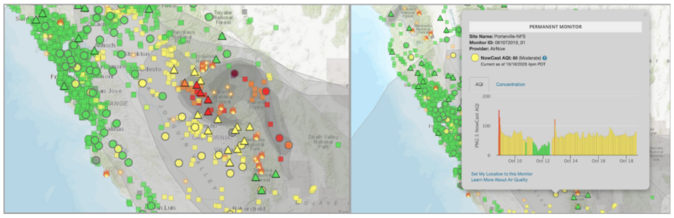


Fig. 3: AirNow Fire and Smoke interactive map. Left: view of the smoke density, fire location, and AQI. Right: by clicking one of the AQI sites, an information box provides relevant information to that particular AQI site location.

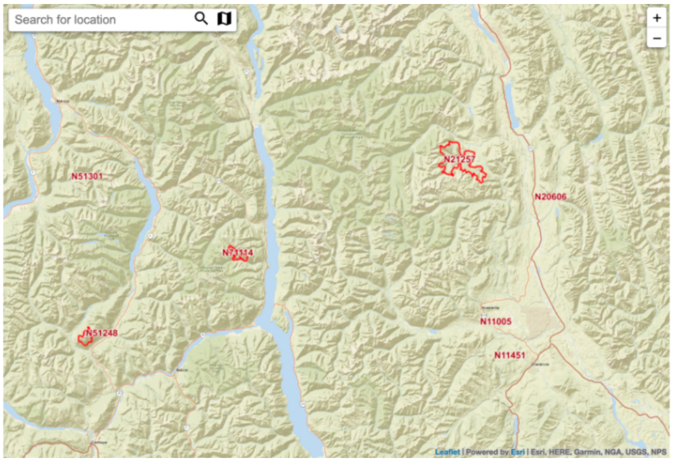



Fig. 4: Current fire perimeters outlined in red and provided by BC Wildfire Service on the BC Data Catalogue [40]. Fires are coded with their fire number in red text.

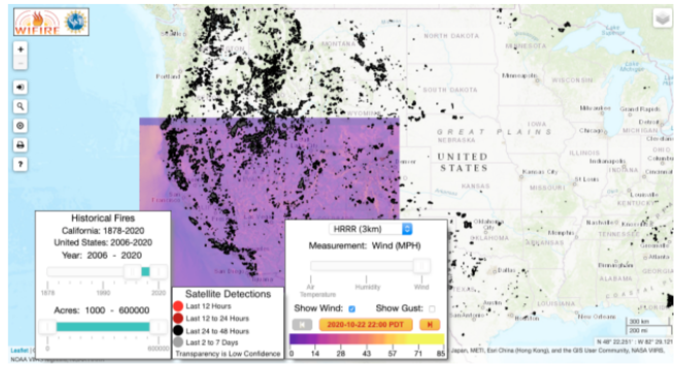



Fig. 5: Different views provided by Firemap [13], designed by researchers at the University of California, San Diego. Historical fires are coded in black, while the weather forecast is represented in the highlighted square region.

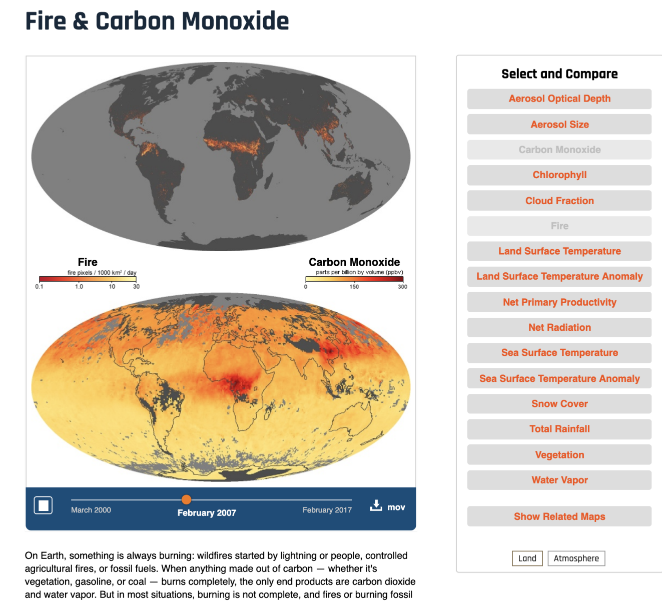



Fig. 6: NASA's Fire Observatory shows an animation of area marks for fires over a geographical map. Right hand menu shows possible comparisons for juxtaposition, all adjoined by time. Timeline allows the user to pause or scrub through to compare different correlations of the fire visualization.

Observatory explores animation of air quality data from March 2000 to August 2020 [36]. Their visualization displays 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 Fig. 6. When any of these map views are clicked to compare, the fire map is juxtaposed to the selected visualization. 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.

In our approach, we plan to facilitate the users to manipulate the map view as per their needs, select elements that they would like to focus on, allow for comparison, and also show them animated views of wildfire related parameters. We also plan to partition our visualizations based on emerging themes so that user can browse as per their specific interests.

### 2.5 Visualization of Geographical Data

The data on wildfires and its related parameters is geographical. We draw inspiration from various geographical data visualizations not directly related to wildfires but developed using similar data attributes.

Covid-19 visualizations by The New York Times [50] and Tableau Community [48] not only show an overall map denoting active cases of people affected using a choropleth map but also go deep into analyzing specific data trends using faceted graphs, tables, and line graphs. Their in-depth analyses show the low level trends which are often not readily accessible in the overview map. The active case attribute is similar to fire incident; hence some of the approaches used in Covid-19 visualizations are transferable.

Other notable visualization projects that are used to draw inspiration are US election maps [2], natural calamity dashboards [20, 42, 46], and weather maps [7].

The field of geographic visualizations has progressed over the years. We looked at tools and platforms that provide access to design of geovisualizations as well as projects that provide geographic datasets. Geographical information system (GIS) frameworks such as arcGIS [3] allow for working with maps and geographic data, and is managed by the Environmental Systems Research Institute. Another mapping platform is Mapbox [32], which supports design of customized maps by providing application programming interfaces. For providing access to geographically referenced data, the research project commonGIS [25] encapsulates enormous amount of spatial data.

## 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 in the data sources from several provinces, there are subtle variations in data frame and types of information collected. For example, notations used to denote the fire class and burn code can vary among sources. However, the general focus is consistent, and most sources include information about fire perimeters, cause of fire, time when the fire was started, areas affected, and geospatial location. In this section, we introduce some of the concepts presented in different sources and that are relevant for contextualizing wildfire information.

### 3.1 Fire Size Classification

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 the definition of large fires as the ones that cause a burned area of 200 hectares or more, as classified in the collected data sources.

### 3.2 Air Quality

As described previously, wildfires have an adverse effect on air quality. Air quality is quantified using the air quality index, which is based on measurements of particulate matter (PM2.5 and PM10), Ozone ($O_3$), Ozone ($O_3$), Nitrogen Dioxide ($NO_2$), Sulfur Dioxide ($SO_2$) and Carbon Monoxide (CO) emissions [19]. Of all these pollutants, fine particulate matter (PM2.5), which is generally present in wildfire smoke, poses the greatest risk to human health [33]. Hence, we decided to focus on measurements of PM2.5 when discussing air quality in the historical analysis of our project.

### 3.3 Source Agencies

The details of wildfires are provided by their respective source agencies. These agencies are usually divided by region, and encompass provinces, territories and areas managed by Parks Canada. We frequently categorize and sort 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 following 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).

### 3.4 British Columbia Air Zones

Part of the historical analysis on air quality presented in this report focuses on the province of BC. Thus, it is helpful to understand some of the regions and characteristics of the area. According to BC Data catalogue [5], air zones are the basis for monitoring, reporting, and taking action on air quality. Air zones are areas which usually exhibit similar features, problems and trends in air quality. BC is divided into seven air zones namely—Northwest, Northeast, Central Interior, Coastal, Southern Interior, Georgia Strait, and Lower Fraser Valley.

BC is also divided based on regions. BC’s eight distinct regions have their own unique geography, climate, economy, history, and cultural diversity [51]. The regions in BC include Vancouver Island/Coast region, Mainland/Southwest region, Thompson-Okanagan, Kootenay, Cariboo, North Coast region, Nechako, and Northeast region.

### 3.5 Wildland Fire Management Expenditures

With wildfires becoming more frequent and its impacts more severe, the Government of Canada annually allocates funds towards efforts to mitigate the effects of wildfires. The wildland fire management expenditures focus on fire safety, preparedness, mitigation, response and recovery costs [27].

## 4 Data Abstraction

We have identified several Canadian data sources for wildfires, air quality indices, climate, 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. Most files accessed through government data websites are available in csv or shape files. Tabular data will help us analyze relevant attributes whereas spatial data will assist us to plot geo-tagged items. We have accessed datasets that include shape files to plot the exact perimeters and regions on a map chart. Tabular data that we acquired can be used directly or manipulated for obtaining derived attributes as needed. The attributes in tabular data are mostly categorical or ordered. Most historic data is available from the year 1930 to 2019, however, 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.

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. Sect. 4.1 to 4.10 discuss the data sources used in Historical Tab whereas Sect. 4.12 to 4.15 discuss the data sources used in Current Tab.

Table 1: Attributes and their descriptions: Wildfire point data

| Attribute Name | Description and Data Type | Attribute Type |
|---|---|---|
| FID | Internal sequential feature number. Automatically generated object identifier. | Categorical |
| Src Agency | The Source Agency (province, territory, parks). | Categorical |
| Fire Id | Agency fire ID. | Categorical |
| Latitude | Latitude. | Quantitative |
| Longitude | Longitude. | Quantitative |
| Year | Year of fire. | Ordinal |
| Month | Month of fire. | Ordinal |
| Day | Day of fire. | Ordinal |
| Size Ha | Fire size (hectares). | 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. Descriptive text. | Categorical |

### 4.1 Wildfire Point Data

Canadian Wildland Fire Information System, Natural Resources Canada [39] provides access to the data in the Canadian National Fire Database (CNFDB). One of these datasets 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, and 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 11 attributes.

- 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

### 4.2 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 levels.

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

| Attribute Name | Description | Attribute Type |
|---|---|---|
| YEAR | Year of fire | Ordinal |
| FIRES | Number of fires | Quantitative |
| TOTAL_HA | Area burned due to fires | Quantitative |
| MAX_SIZE_HA | Maximum size of fire in hectares | Quantitative |
| FIRES>200ha | Number of large fires | Quantitative |
| TOTAL_HA(>200ha) | Area burned due to large fires | 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 | Quantitative |
| SRC AGENCY | Province / source agency / territory. 13 possible values (AB, BC, MB, NS, NWT, ON, PEI, PC, QC, SK, YT, NL, NB) | Categorical |

#### 4.2.1 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.

- 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

#### 4.2.2 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.

- 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

### 4.3 Wildfire Polygon Data

The data in the CNFDB also consists of a data set called the NFDB polygon data which contains geometrical shapes of the fire perimeters and the details of fires that occurred in Canada from the year 1917 through 2019. This data consists of 413151 rows, each belonging to one Fire Id. While the actual data has 27 attributes, we use the ones most relevant to our visualizations and the attributes which were present for all fires. These attributes include Fire Id, day month, year, the geometry for location, cause and the size of fire in hectares.

- Data Types: Items and positions. This data consists of attributes of type ordered, categorical and geometrical. Domain specific description - Each item corresponds to a fire Id.
- Dataset Type: Spatial
- Dataset availability: Static

Table 4: Attributes and their descriptions: AHCCD

| Attribute Name | Description | Attribute Type |
|---|---|---|
| lat | Latitude | Quantitative |
| long | Longitude | Quantitative |
| province__province | Province | Categorical |
| date | Start date of measurements | Ordinal |
| temp_mean | Mean temperature (C) | Quantitative |
| temp_max | Maximum temperature (C) | Quantitative |
| temp_min | Maximum temperature (C) | Quantitative |
| total_precip | Total precipitation (mm/period) | Quantitative |
| rain | Rainfall (mm/period) | Quantitative |
| snow__neige | Snowfall (mm/period) | Quantitative |
| wind_speed | Wind speed (m/s) | Quantitative |

### 4.4 Adjusted and Homogenized Canadian Climate Data

The Adjusted and Homogenized Canadian Climate Data (AHCCD) [18] 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.

- 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

### 4.5 National Air Pollution Surveillance: Data-Donnees

The National Air Pollution Surveillance (NAPS) program [17], 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 ($NO_2$)
- nitric oxide (NO)
- nitrogen oxides (NOX)
- ozone ($O_3$)
- sulfur dioxide ($SO_2$)

- particulate matter less than or equal to 2.5 (PM2.5) and 10 micrometers (PM10)

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 quarterly 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 [29] to gather all files locally. After obtaining all files locally, we had access to a folder structure with one folder for every year and further sub-folders with multiple csv and json files for continuous data including annual summaries and hourly data, and json files for integrated data. This data was not consistent in terms of availability across all years. Also, since there were different files for the pollutants mentioned, and data was accessible at hourly level, it was decided to work with continuous hourly PM2.5 data as that allowed to us to aggregate it according to the level required for analysis. Looking at the data in detail, it was found that the data for PM2.5 is available for the years 1995 to 2018. Each yearly file provided access to PM2.5 levels for all days of the year in an hourly format, for all measurement cities. The PM2.5 values are measured in µg/m3. Thus, one row corresponds to data from one day of the year for one city. Further, 24 columns for the recorded PM2.5 levels are available, one for each hour of the day. It was decided to process the data into a more accessible format. Data was narrowed down in a way that instead of hourly values, a day average of PM2.5 level was calculated to further obtain a monthly average. Since wildfires often span over multiple days, using a monthly average was more feasible. All data was consolidated into one file to include the year, month, city, province and the PM2.5 value as attributes. Thus, for a city, we obtained the monthly average value over the years. The data contains 30285 rows and 5 columns. A separate file was used to store the exact locations using latitude and longitude for every city, making up for 205 rows and 3 columns.

- Data Types: Items and attributes. This data consists of attributes of type categorical, quantitative and ordinal.
- Dataset Type: Table
- Dataset availability: Static

### 4.6 BC Air Zones Shapes Albers System

BC Data Catalogue provides data as a spatial file containing polygon geometries of the air zones of BC [5]. The names of the air zones support the geometry. This shape file is provided as part of the EPSG_3005 - NAD83 BC Albers spatial reference system.

- Data Types: Items and positions. This data consists of attributes of type categorical and geometrical. Domain specific description - Each item corresponds to an air zone of BC and its corresponding polygon shape.
- Dataset Type: Spatial
- Dataset availability: Static

### 4.7 BC Air Zones and Regions

To support analysis at different levels of granularity and to use the BC Air Zones shape file, a dataset was manually created to contain attributes representing the air zones and regions that each city in BC belonged to. All cities of BC available in the PM2.5 data from the NAPS program were extracted and assigned to their respective air zones and regions.

- Data Types: Items and attributes. This data consists of attributes of type categorical. Domain specific description - Each item corresponds to a city in BC. The name of the air zones and the region are two additional attributes.
- Dataset Type: Table
- Dataset availability: Static

### 4.8 Forest Area for Canadian Regions

Data for forest land area by Canadian provinces and territories was manually extracted from [44].

- Data Types: Items and attributes. This data consists of attributes of type categorical and quantitative. Domain specific description - Each item corresponds to region or province and its corresponding forest area in thousands of hectares.
- Dataset Type: Table
- Dataset availability: Static

### 4.9 Cost of Wildland Fire Protection

Data for government expenditure on fire mitigation efforts was extracted from forest change indicators provided by the Government of Canada [23]. This data was saved in a tabular format and includes fire protection costs in Canada for the years 1970 to 2017.

- Data Types: Items and attributes. This data consists of attributes of type ordered. Domain specific description - Each item corresponds to a year and its associated total fire expenditure.
- Dataset Type: Table
- Dataset availability: Static

### 4.10 Property Losses Due to Wildfires

The National Forestry Database Forest Fires data [37] provides access to property losses in dollars for provinces (called ISO's) from the year 1990 to 2018. Even though this data is recent, it has a lot of missing data. Missing data values were not considered in analysis.

- Data Types: Items and attributes. This data consists of attributes of type ordered. Domain specific description - Each item corresponds to a year and ISO and its associated property loss value in dollars.
- Dataset Type: Table
- Dataset availability: Static

### 4.11 Data Relationships for Historical Data

For the datasets mentioned for use in the historical tab so far, relationships between attributes were used to analyze the data collectively. Fig. 7 shows the relationships between the multiple datasets used in the analysis.

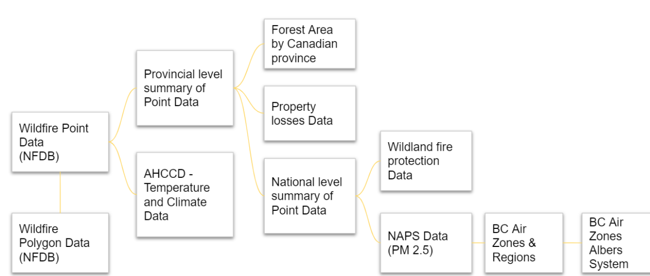



Fig. 7: Dataset relationships for the historical tab.

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

Table 5: 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 | Ordinal |
| SIZE_HA | area within the outside perimeter of the incident, in hectares | 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 |

### 4.12 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 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 micrometers or less) in micrograms per cubic meter (ug/m3)
- PM10 (particulate matter with diameter of 10 micrometers or less) in ug/m3

### 4.13 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 5 shows the data-specific descriptions and types of attribute.

### 4.14 BC Data Catalogue: Information Bulletins

BC Catalogue Information Bulletinst [6] segment includes both current and archived information bulletins from the BC Wildfire Service and press releases concerning wildfire issues of interest.

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

| Attribute Name | Description | Attribute Type |
|---|---|---|
| AREA | smoke plume size in acres | Ordinal |
| START_DATE | date at the time of smoke plume data collection | Ordinal |
| LAT | latitude | Quantitative |
| LONG | longitude | Quantitative |

### 4.15 The Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SmartFire) 2.0: Smoke Plumes

SmartFire 2.0 provides smoke plume data in the form of shape files. These are the relative size and shape of the smoke coverage over a particular geographic location. The data is updated hourly and has historical smoke plume data available as well. The shape files overlap one another to depict density in a particular area. SmartFire 2.0 combines multiple sources for creating the shape files and avoids double counting for accurate smoke plume readings. As a project to reconcile the framework of FireSmoke.ca, SmartFire 2.0 is a geographic information system (GIS) for the FireSmoke.ca database. Table 6 shows the data descriptions and types.

### 4.16 Data Relationships for Current Data

For the datasets mentioned for use in the current tab so far, relationships between attributes were used to plot the data collectively. Fig. 8 shows the relationships between the multiple datasets used.

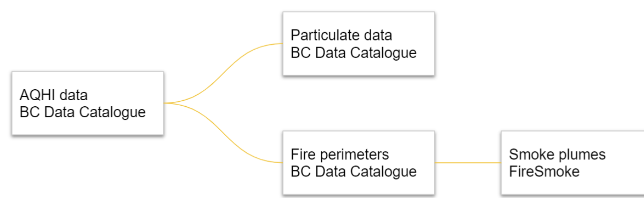



Fig. 8: Dataset relationships for the current tab.

## 5 Task Abstraction

On a general basis, users need a comprehensive resource having all the information related to wildfire. Users may *explore* as well as *consume* information about active fires, air quality, smoke plumes, and historical trends. Targeted users like local residents and campers may need to *browse* or *look-up* specific information such as wildfire perimeter, high risk zones, regional warnings, and smoke coverage.

In that respect, on a higher-level, Firest aims to 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 example, 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 example, "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 provide curated information on wildfires. 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 example, 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 relevant 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.

### 5.3 Requirement Analysis

Based on the research performed on existing work in literature as well as the different practical tools and websites related to wildfires, we realized a need for Firest. Keeping all users, actions and targets in mind, our interface aims to cater to the following requirements:

**R1: Encompassing all information on wildfires in one place.** Firest should be able to provide information about wildfires including current state and historical analysis in a single interface without having to search for separate resources.

**R2: Provide analysis results and visualization of historical data.** Firest should provide results and dashboards comprising of all major aspects of related to wildfires. A user should be able to view any dependent factors such as wildfire regions, forest areas, effect of wildfires on environmental metrics such as air quality and temperature, and the effect on economy. This interface should be available for use by anyone seeking information on wildfires including citizens, researchers or people who may be interested about this field.

**R3: View the current state of wildfires.** Firest should provide an interface for users to view current fire regions, air quality metrics, smoke coverage, and bulletins and alerts together in a single dashboard. This view should hence provide real-time information for use by residents and campers.

## 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 fire perimeters, air quality parameters and climate data related to wildfires. The historical tab will show the results gathered from the analysis of various historical datasets covering wildfire points directly, economic effects, regional characteristics, summarized high level view of wildfires, temperature and pollution variations and any inherent trends over the course of time. In this section, we talk in detail about various visualization idioms used and discuss the complete design process and the choices considered before reaching the final design. We thus present elements that act as building blocks of higher level dashboards discussed in Sect. 8.

### 6.1 Historical Tab: Visualizations and Design Choices

The analysis of historical data involved creation of multiple visualization. These individual components including interactive maps and charts eventually become a part of dashboards, and are described below. At points where the data was very large, extremely granular or missing altogether, we created some charts to view the availability of the data itself. We include these visualizations here as well.

#### 6.1.1 Location and Cause of Fires

Our analysis started with the most basic question: "Where were the historical fires located?". The task is to locate points and to find any extreme points. We considered multiple options to visualize the locations of past wildfires.

Design choices considered

1. Using the wildfire point data, we plotted the locations of wildfires using the quantitative attribute values of latitude and longitude associated with each fire point. We use a scatter plot on a map chart to plot the wildfires as shown in Fig. 9. The horizontal axis plots the latitude and the vertical axis plots the longitude values. 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 drop-down list. The quantitative attribute size dynamically aggregates into size range 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.

   While this visualization is useful for viewing the availability of data itself, it is not intuitive enough for the theme of wildfires. We

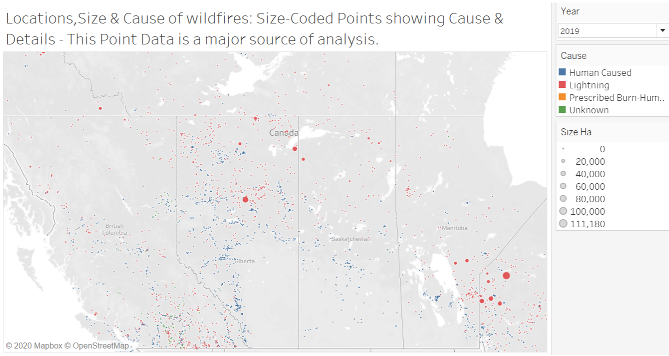



Fig. 9: Locations and Cause of Fires using wildfire point data.

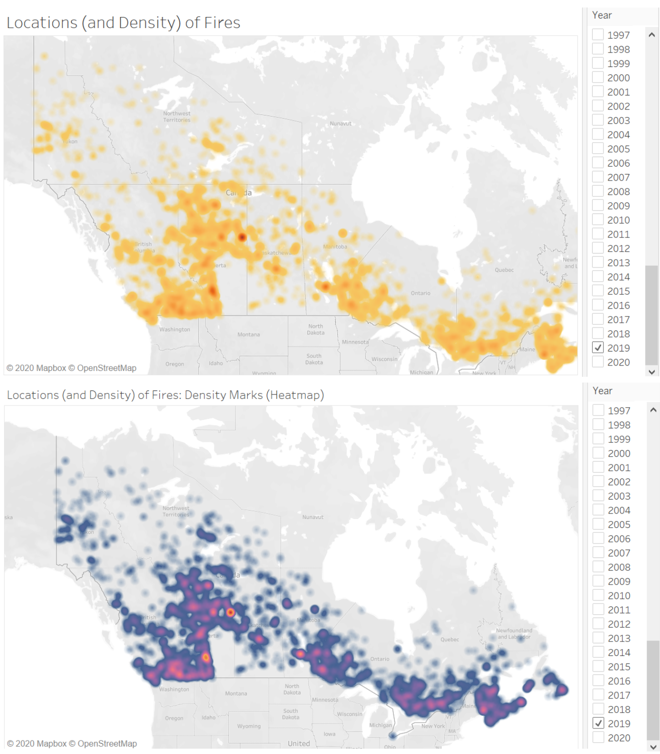



Fig. 10: Locations with density using wildfire point data.

consider this design choice for only showing and understanding the data as this point dataset is a major basis of our further analysis. However, for the purpose of visualizing wildfires, we considered more design choices as follows.

2. In trying to use the wildfire point data in a more instinctive way, we considered plotting the wildfire points as a heat map that shows the density of fires. This map with different color schemes is shown in Fig. 10.

   *Marks and Channels:*

   - Density mark encodes a wildfire point (a Fire Id).
   - Sequential color encodes the intensity or the number of marks of fire.
   - Tooltip provides more information about the wildfire point when hovered over a particular point.

   The idiom used here is a density heatmap on a geographic map. While the overlapping points show density very accurately and allows us to locate areas with a large number of fires, we now cannot color-encode the cause of the fire as that channel is already used.

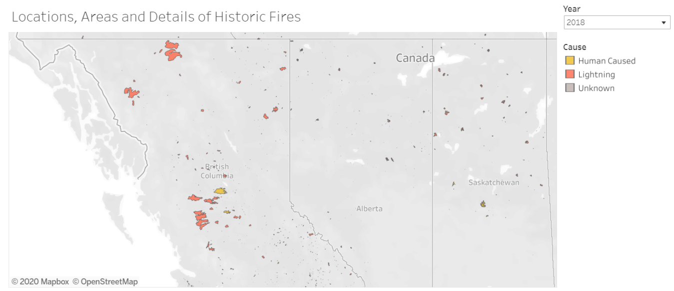



Fig. 11: Exact shapes and locations using wildfire polygon data.

3. Since the point data does not have geometry information of the fires, we decided to use the wildfire polygon data. This dataset provides exact polygon regions for the wildfires. The idiom of a thematic geographic chart is used here. We plotted the polygon geometry on a map as seen in Fig. 11. The latitude and longitude values are automatically generated. The color of the shape represents the type of the categorical variable cause.

   *Marks and Channels:*

   - Shape mark encodes a wildfire point (a Fire ID).
   - Color encodes the cause of fire.
   - Tooltip provides more information about the wildfire point when hovered over a particular point as shown in Fig. 12. Details include: Fire ID, day, month, year, cause of fires and the size in hectares.

   *Filters and Interactivity:*

   - A multiple value drop-down list filter is used to provide interactivity for selecting the ordinal attribute year. This enables reducing views to the desired level of detail and showing fires corresponding to selected years.
   - Manipulating Views
     - Highlighting a cause in the color legend reduces the view to only show wildfires caused by the selected category. As shown in Fig. 13, 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 to provide 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" [35]. 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 tooltip can be viewed, and the map itself can be zoomed in and out.

   This is our final design choice as it is thematic and viewing the actual regions of fire makes it easy to understand and provides a natural and geographic perspective.

4. 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.

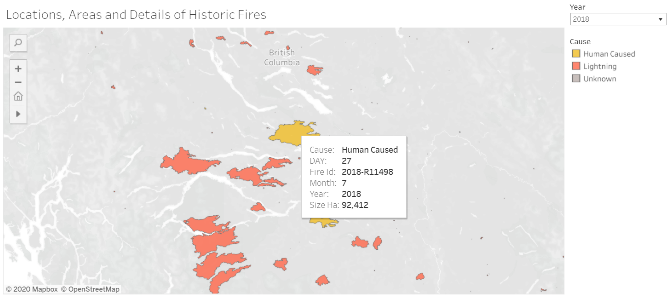



Fig. 12: View when hovering a tooltip over a fire region.

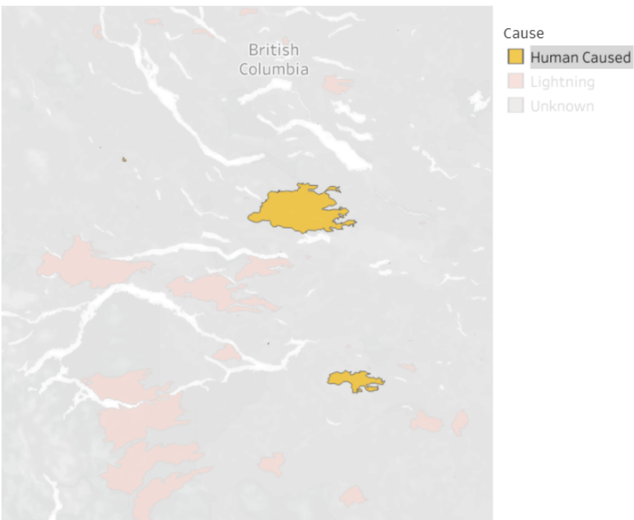
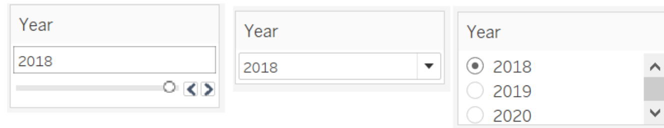
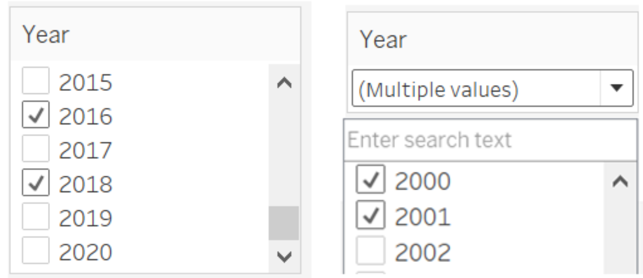



Fig. 13: Highlighting a cause of fire in the legend causes fires with only that cause to show in the map.




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




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

Fig. 14: Design choices for the filter card 'Year'

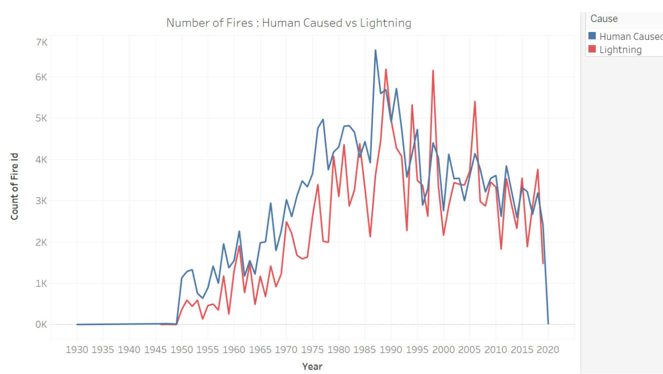



Fig. 15: Comparison of number of fires: human caused and lightning caused using multiple line charts.

5. For the filter "Year", we considered multiple options available as shown in Fig. 14. We provided the option for selecting multiple years at a time, using a drop-down menu, if the users wanted to see data over a range of years.

#### 6.1.2 Comparison of Cause of Fire

Looking at the points of wildfires over multiple years, it appeared that the cause of fire was mostly either natural or human induced. Further, we wanted to analyze if the number of fires caused by humans was more than the number of fires caused by lightning. To lookup and compare the reason behind wildfires, the wildfire point data was employed. We plotted the number of fires over the years, differentiated by the two most common causes: human and lightning (natural). The design choices considered are described below. In each case, 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.

##### Design choices considered

1. We first plotted the number of fires over the years as a line chart, with separate lines for human caused and lightning, as shown in Fig. 15.

   *Marks and Channels:*

   - 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.

2. An 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 using a line chart and a bar chart as shown in Fig. 16 and Fig. 17, respectively. We made this decision keeping in mind that for tasks that require understanding a difference, encoding the difference directly enables judgment of position along a common frame [35].

   *Marks and Channels:*

   - For the line chart in Fig. 16:
     – Points connected by line connection marks encode the difference between the number of human caused and lightning caused fires.
   - For the bar chart in Fig. 17:
     – Line marks (bar) encode the magnitude of the difference between the number of human caused and lightning caused fires.
     – Horizontal spatial position channel separates the years.

   The chart in Fig. 15 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

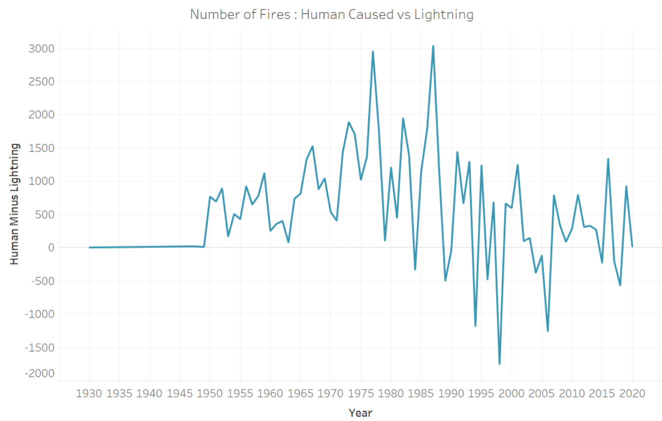



Fig. 16: Comparison of number of fires: human caused and lightning caused using a line chart showing the difference.

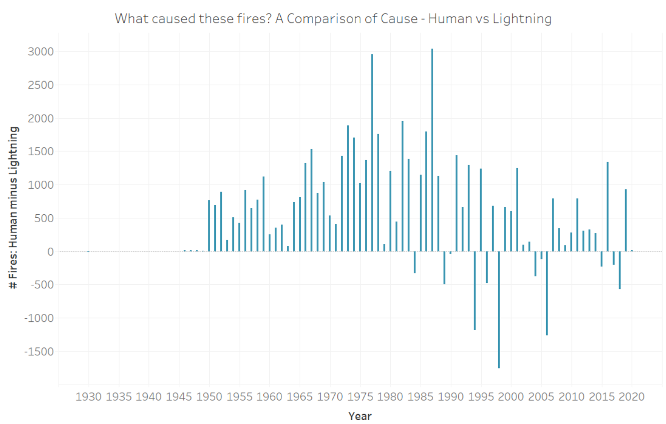



Fig. 17: Comparison of number of fires: human caused and lightning caused. Final choice is a bar chart.

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. Our final choice of idiom is thus the bar chart shown in Fig. 17.

### 6.1.3 Wildfire Months

We wanted to determine the months in which occurrence of wildfires is most common. This task involves looking up and comparing number of fires varying over different months, and thus obtaining its distribution.

Design choice We plotted the count of number of fires over all years for each month. This is shown in Fig. 18, 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) with the vertical spatial position channel encodes the count of fires.
- Horizontal spatial position channel differentiates the months.

We had a general 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. We also wanted to identify core fire months for further analysis. For the rest of the report, we consider May to August to be core fire months, while others as non-core fire months.

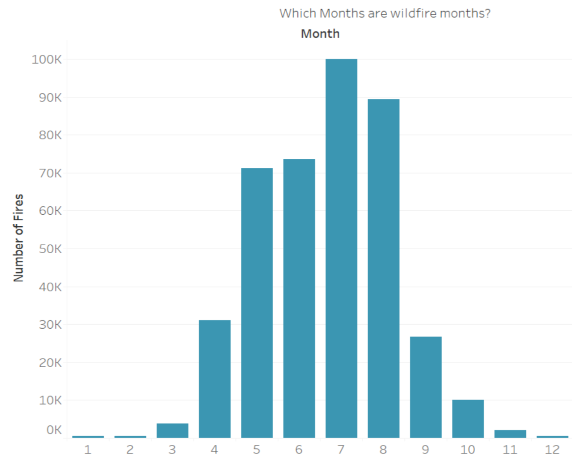



Fig. 18: Determining the wildfire months

### 6.1.4 Fires Within Each Region

The next step was to determine the regions with the largest number of wildfires. This would help us to focus on regions or provinces which are most affected by wildfire.

Design choice We plotted the count of number of fires, i.e., count of Fire Id, for each region. This is shown in Fig. 19, 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. The aim here is to lookup to find the maximum value by comparing values of the quantitative attribute over the categorical attribute.

*Marks and Channels:*

- Line mark (bar) encodes the count of fires.
- Mark label to annotate the count of fires over the line bars.
- Horizontal spatial position channel for the different source agencies.

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.

### 6.1.5 Fire Count vs Forest Area

Now that we have visualized the regions with large number of fires, finding if there is a relation between forest area and the number of fires would support the analysis. The task here is to lookup to find trends and dependencies between forest area and number of fires. Thus for the design choices considered below, the values we want to compare are quantitative attributes, number of Fires and Forest Area. To differentiate the regions, we use the Src Agency (source agency) as the categorical attribute.

Design choices considered

1. 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 as shown in Fig. 20.

   *Marks and Channels:*

   - 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.

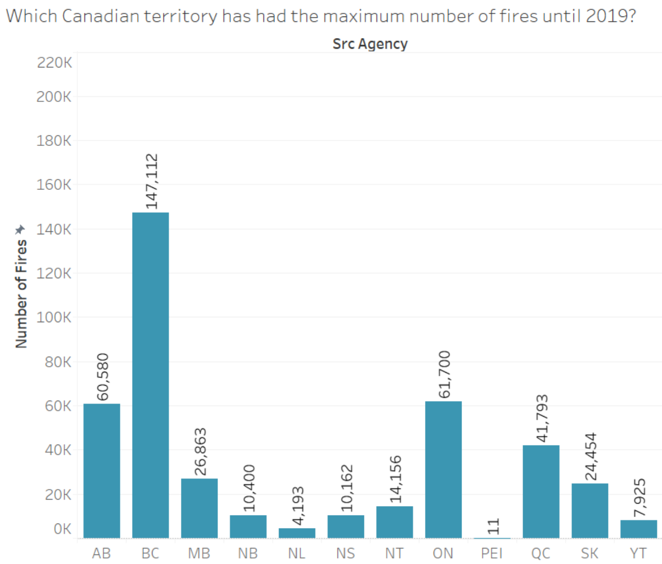



Fig. 19: Determining the region with largest number of fires.

This design choice is not preferred as it may represent a non-existent causality due to the the way the forest area is presented using area marks.

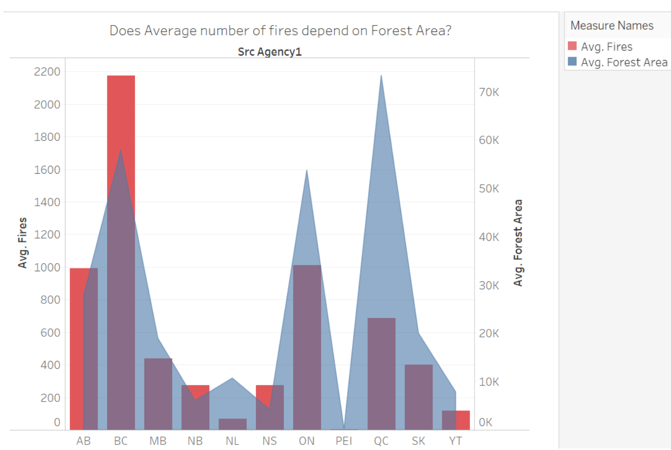



Fig. 20: Using area marks for forest area and line marks for average number of fires.

2. We now approach this task by visualizing a part-to-whole relationship, comparing the proportion of the number of fires as well as the forest cover for a given region. We use the idiom of pie charts to represent the part-to-whole relationship for the two quantitative attribute on two separate graphs and then putting them side by side for comparison, as shown on Fig. 21.

   *Marks and Channels:*

   - Proportional area / wedges with angle channel encodes the quantitative attribute average number of fires in the pie chart on the left of Fig. 21.
   - Proportional area / wedges with angle channel encodes the quantitative attribute forest area in the pie chart on the right of Fig. 21.
   - Color encodes the categorical attribute Src Agency (source agency).

3. We also plot this part-to-whole relationship using to stacked bar charts instead of pie charts as shown in Fig. 22.

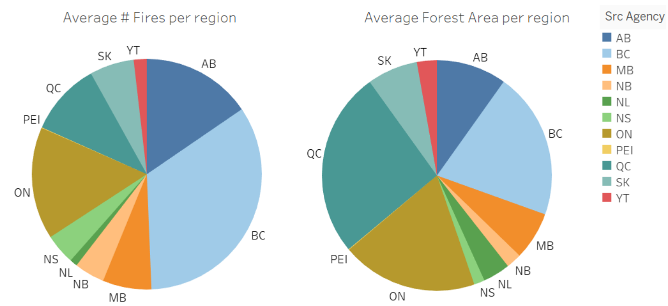



Fig. 21: Using a pie chart to represent forest area and average number of fires.

*Marks and Channels:*

- 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. 22.
- 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. 22.
- Color encodes the categorical attribute Src Agency (source agency).

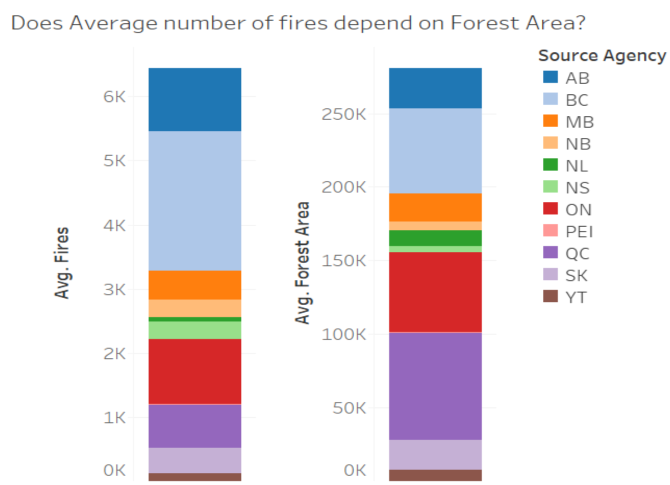



Fig. 22: Using a stacked bar charts to represent forest area and average number of fires.

Comparing the choices in Fig. 21 and Fig. 22, we preferred Fig. 22 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. Fig. 21 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. Thus, our final choice of graph is shown in Fig. 22, which uses the idiom of stacked bar charts.

#### 6.1.6 Fire Count vs Total Burned Area

To evaluate the contribution of large fires in terms of number of fires and area burned, we created multiple visualizations as discussed below. The major task is to lookup and compare values.

Design choices considered

1. 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. 23. 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 200 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. 23:
     - 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. 23:
     - 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).

   Fig. 23 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.

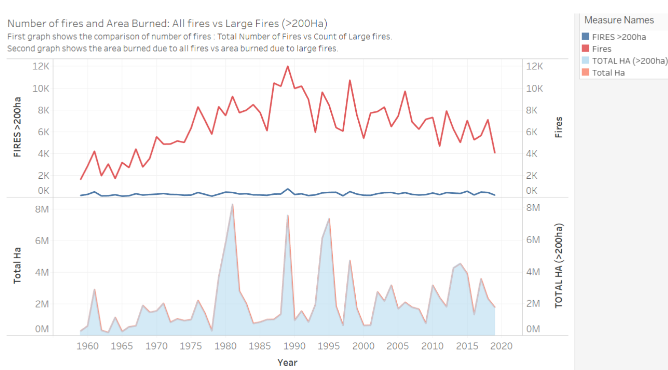



Fig. 23: Design choices for comparing the number of fires and the total burned area: Number of fires and Area Burned - All fires vs Large Fires ($>$ 200Ha)

2. We wanted to summarize this information into one graph. To do so, we derived quantitative attributes calculating the proportion of number of large fires in total number of fires, as well as the proportion of area burned due to large fires in total area burned. These two quantitative variables were then plotted on the same graph using the idiom of line charts as shown in Fig. 24.

   *Marks and Channels:*

   - 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

   The use of percentages in Fig. 24 allows for a faster identification of trends over the years for the large fires. This graph complements the information provided in Fig. 23. It directly shows 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.

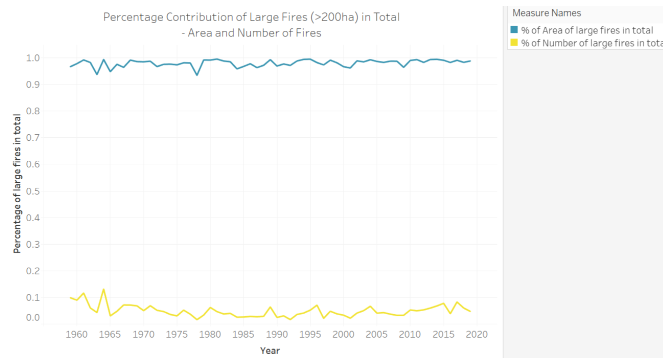



Fig. 24: Percentage of area and number of fires: All vs Large Fires

### 6.1.7 Annual Number of Forest Fires

We wanted to understand the high level historical trend of in occurrence of fires over the years. The task here is to lookup and compare values of number of fires varying over the years.

Design choice We plotted the count of number of fires over the years from 1960 to 2020 using the idiom of a line chart. This is shown in Fig. 25, 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.

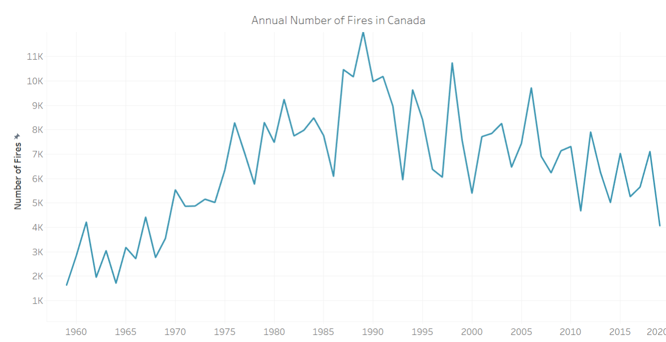



Fig. 25: Design choice for analysis of number of fires per year.

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.

### 6.1.8 Air Quality PM2.5 visualizations

Now that we have enough information about wildfire points, we move on to visualizing details about PM2.5 using the data obtained from the NAPS program. This is required to analyze the effect that wildfires have on air quality. Visualizing trends in pollution levels and comparing these in presence and absence of wildfires is a major task here. For each design choice, we plot the quantitative attribute PM2.5 aggregated over different granularity levels such as year or month.

## Design choices considered

1. To understand the data, we started with a visualization that plots the average PM2.5 values over the years for all cities in the data. Here city is a categorical variable. This plot uses the idiom of superimposed line charts, and is shown in Fig. 26.

   *Marks and Channels:*

   - Points connected by line connection marks encode the average PM2.5 value for a given city. Superimposed line layers, with one line for each city.
   - Color encodes the city.

   This design choice is clearly not feasible as the idiom does not scale to so many cities.

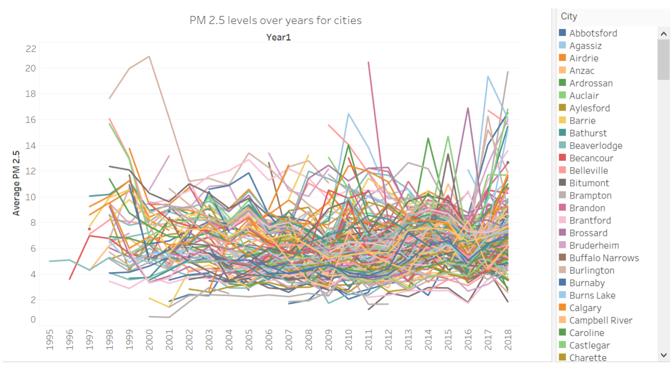



Fig. 26: PM2.5 values for all cities over the years.

2. The data is very detailed and thus we had to visualize content at a more aggregated level. The yearly averages of PM2.5 levels were plotted for regions in BC, which is a categorical attribute. The idiom used is a box plot and is shown in Fig. 27.

   *Marks and Channels:*

   - One glyph for every region in BC shows the five derived summary statistics using vertical spatial position.
   - Points show exact value of PM2.5 for each year.

   This is an understandable and useful plot. However, since we see scope to represent data at monthly level, we consider more choices, as follows.

3. Since using regions looks manageable and it would be more useful to get monthly averages to analyze the effect of wildfires, we now plotted the monthly averages for regions of BC. Again, the idiom used is a box plot and is shown in Fig. 28.

   *Marks and Channels:*

   - One glyph for every region in BC shows the five derived summary statistics using vertical spatial position.
   - Points show exact value of PM2.5 for each month.
   - Color encodes the month.

   We choose this graph as it provides information of PM2.5 values for months across regions of BC. The graph is also effective in identifying higher values like the ones seen in the month August.

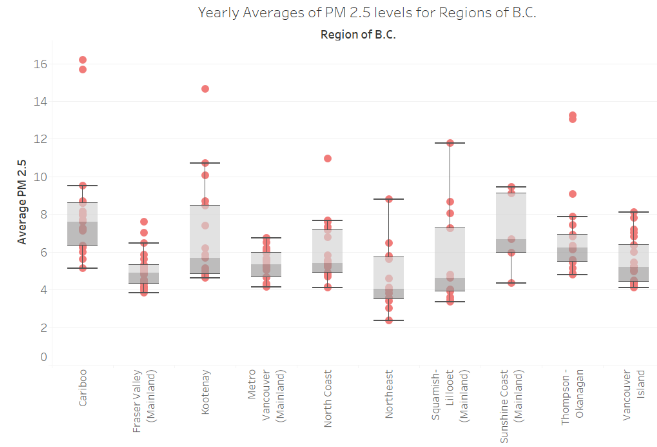



Fig. 27: Yearly PM2.5 averages for regions in BC.

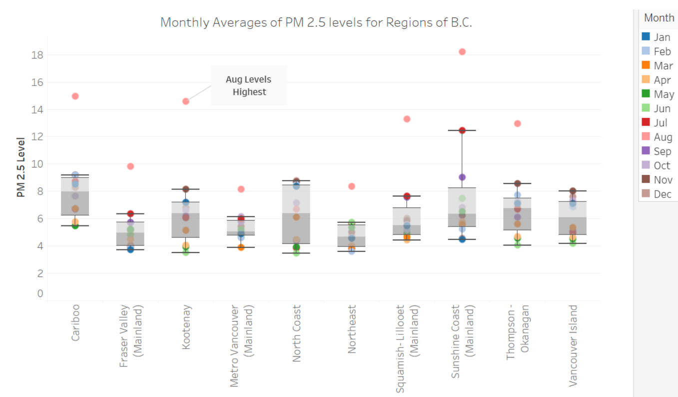



Fig. 28: Monthly PM2.5 averages for regions in BC.

4. Before plotting the PM2.5 averages for air zones of BC, we plotted the measurement stations to understand the availability and source of data. These locations are plotted as a scatterplot on top of a geographic map chart in Fig. 29. Locations of measurement station city are obtained using the quantitative attributes latitude and longitude.

   *Marks and Channels:*

   - Circle point encodes a measurement station city.
   - Color encodes the air zone of BC.
   - Tooltip provides more information about the measurement station when hovered over a particular point. Details include: city, air zone, latitude and longitude.

   We use this visualization as a means to support the understanding the source of data.

5. To support comparison in air zones of BC, the monthly averages were plotted for air zones of BC, which is a categorical attribute. This graph will support charts we create further to support comparison of wildfire months against non wildfire months, and is shown in Fig. 30.

   *Marks and Channels:*

   - One glyph for every air zone in BC shows the five derived summary statistics using vertical spatial position.
   - Points show exact value of PM2.5 for each month.
   - Color encodes the month.

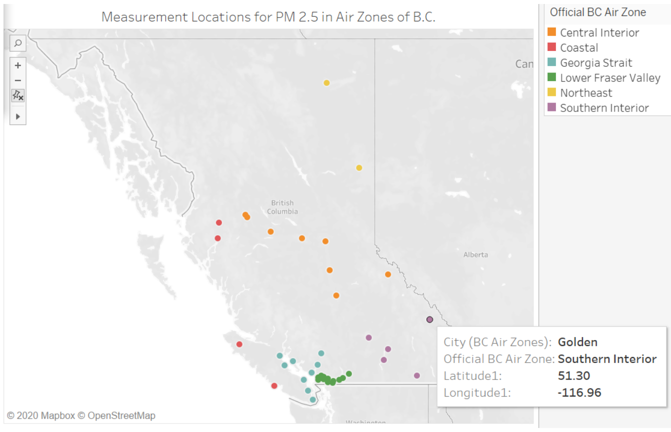



Fig. 29: Measurement stations for PM2.5 in air zones of BC.

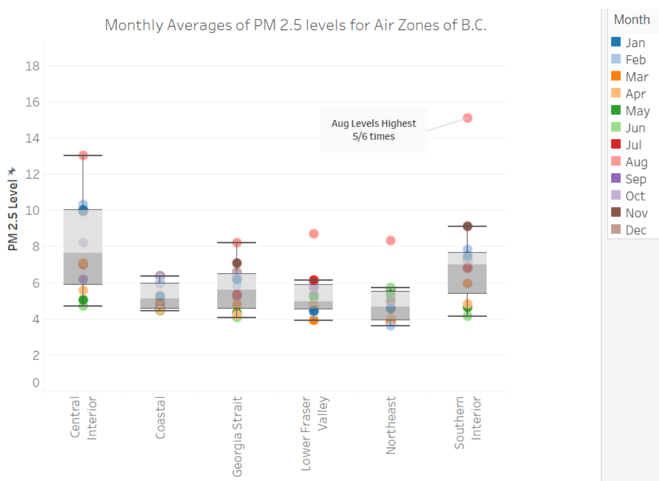



Fig. 30: Monthly PM2.5 averages for air zones in BC.

### 6.1.9 BC Air Zone shapes and PM2.5

While the PM2.5 data has been analyzed using boxplots for monthly and yearly levels and for both regions and air zones, we wanted to visualize these values more intuitively by displaying data for regional shapes as a thematic map. We extended the visualizations described above to integrate them with a shape file containing polygons for BC air zones.

#### Design choices considered

1. Using the BC air zones shape file and the NAPS program PM2.5 data together, we plotted PM2.5 averages aggregated yearly for different air zones. This was then plotted as a choropleth map and is shown in Fig. 31.

   *Marks and Channels:*

   - Space area mark boundaries encode the geometry polygons of BC air zones.
   - Sequential color encodes the value of PM2.5 levels.
   - Text annotation over region encodes exact value of PM2.5 level.
   - Tooltip shows the name of air zone and the PM2.5 value.

   This map is particularly useful to understand the availability of PM2.5 data across different air zones of BC through the years. This helps validate the aggregation and relationships between datasets that we manually created to represent the values of PM2.5 data.

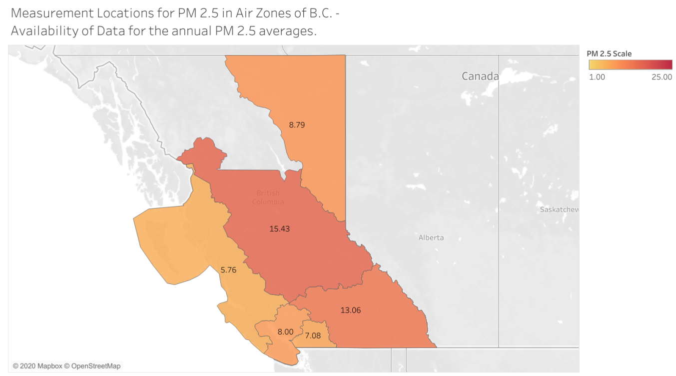



Fig. 31: Yearly PM2.5 averages for air zones in BC shown as a choropleth.

2. The choropleth shown in Fig. 31 was then customized using filtered months to aid comparison of PM2.5 levels during core wildfire months against non-core fire months. We thus create two choropleth maps for both sets of months as shown in Fig. 32 and Fig. 33. Given a year, we can now compare the maps for the values of the pollutant.

   *Marks and Channels:*

   - The marks and channels remain same as the previous choropleth map. We only changed the color scheme to a sequential red instead of a sequential orange.

   *Filters and Interactivity:*

   - A multiple value list drop-down filter is provided to dynamically select years for which the PM2.5 values must be aggregated and displayed on the choropleth map.

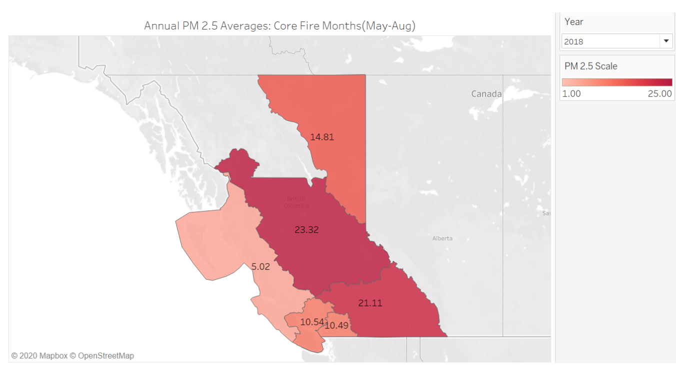



Fig. 32: Yearly PM2.5 averages for air zones in BC shown as a choropleth for the core fire months May-August.

### 6.1.10 Weather Monitoring: Precipitation, Temperature and Wind Speed

Since weather and wildfires heavily impact each other, we decided to showcase the annual trends in three main climate parameters: precipitation, temperature and wind speed. The information displayed in this dashboard is derived from the AHCCD dataset.

#### Design choices considered

1. Initially, we considered displaying weather trends by calculating the year over year percent difference for each parameter. We generated two different idioms to convey this information, as shown in Fig. 34 and Fig. 35. However, since the weather monitoring stations vary over the years, this view can guide the user

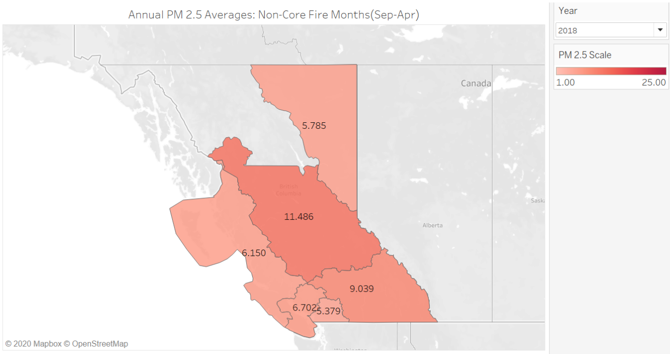



Fig. 33: Yearly PM2.5 averages for air zones in BC shown as a choropleth for the non-core fire months September-April.

towards misleading comparisons. For instance, a spike in the percent difference of precipitation between the years 1956 and 1957 for British Columbia could be related to the installation of new monitoring stations at different regions of the province, instead of a relevant climate phenomena. Thus, we have decided to only display general monthly trends for each parameter, shown in Fig. 38, Fig. 40 and Fig. 43.

2. We also performed a high-level correlation analysis for each parameter, as exemplified by Fig. 39 and Fig. 42. Following the same reasoning of varying monitoring stations discussed for charts Fig. 34 and Fig. 34, these views were omitted from the final solution.

3. For precipitation, at first, we considered having separate charts for snowfall and rainfall, as shows Fig. 36 and Fig. 37. However, this information can be condensed into a single chart conveying the same information, which is represented by Fig. 38.

*Marks and Channels:*

- For the line chart in Fig. 34:
  - Points connected by line connection marks encode the year over year percent difference of rainfall.
- For the bar chart in Fig. 35:
  - Line mark (bar) encodes the percent difference of rainfall.
  - Horizontal spatial position channel separates the years.
- For the line charts in Fig. 36 to Fig. 38, Fig. 40, and Fig. 43:
  - Points connected by line connection marks encode the monthly average for the weather parameter (precipitation, temperature or wind speed).
  - In Fig. 40, color encodes the type of temperature (minimum, mean or maximum temperature).
- For the heatmaps, as exemplified in Fig. 39, Fig. 42 and Fig. 44:
  - 2D matrix alignment encodes year (vertical axis) and province (horizontal axis).
  - Color encodes the magnitude of Pearson's correlation between the total area burned and the weather parameter (precipitation, temperature or wind speed).

*Filters and Interactivity:* For the final choices, the following interactivity options are available:

- A multiple value list drop-down page filter is provided to dynamically select year for which the weather parameter (temperature, precipitation and wind speed) values must be aggregated and displayed on each respective line chart. This control also enables looping playback on Tableau.
- A multiple value list drop-down simple filter is provided to dynamically select the provinces for which the weather parameter (temperature, precipitation and wind speed) values must be aggregated and displayed on each respective line chart.
- A tooltip displaying the average value for the parameter (temperature, precipitation or wind speed), the date (year and month), and the number of fires and total area burned for the same date, is displayed upon hover over any of the line charts in the final dashboard, as exemplified in Fig. 41.

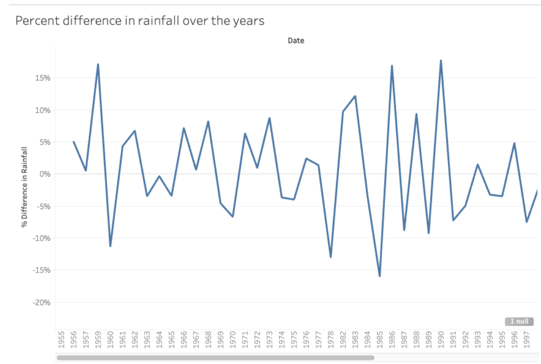



Fig. 34: Year over year percent difference of rainfall (line chart)

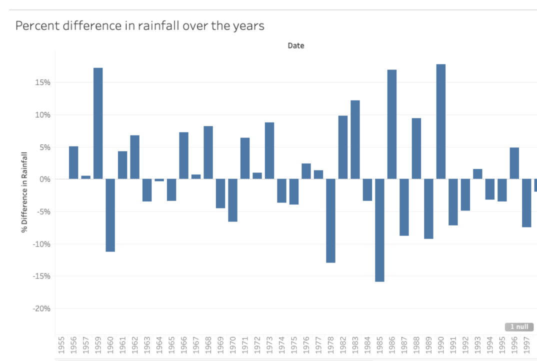



Fig. 35: Year over year percent difference of rainfall (bar chart)

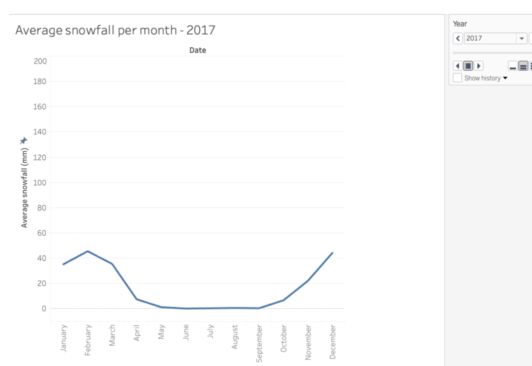



Fig. 36: Average snowfall per month

### 6.1.11 Weather Monitoring: Stations

Since the number of and locations of weather monitoring stations vary over the years, we decided to display this information in the dashboard, as shown in Fig. 45.

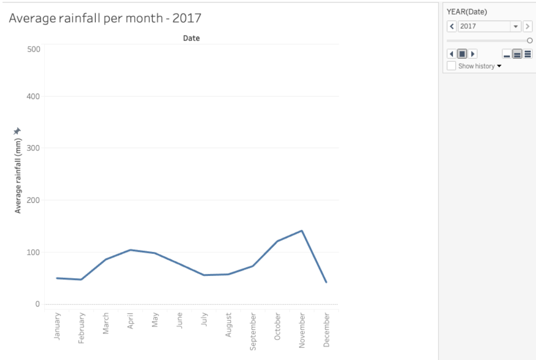



Fig. 37: Average rainfall per month

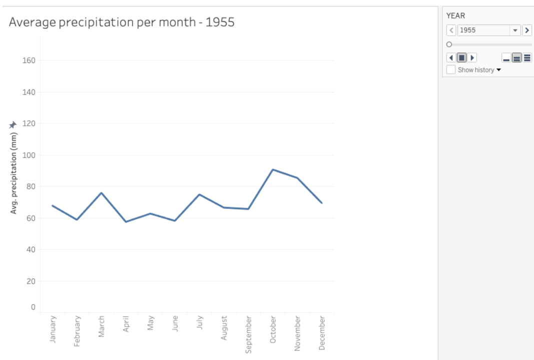



Fig. 38: Average total precipitation per month

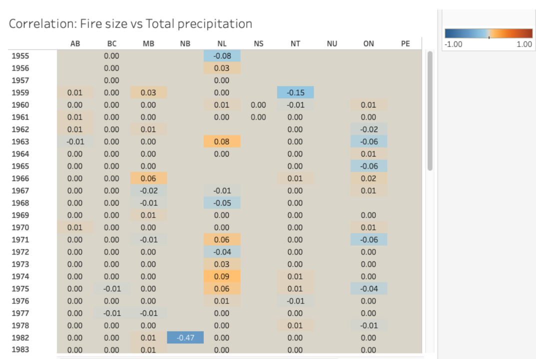



Fig. 39: Correlation between fire size and total precipitation

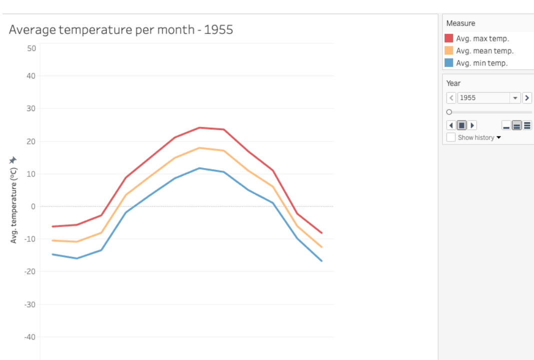



Fig. 40: Average temperature per month

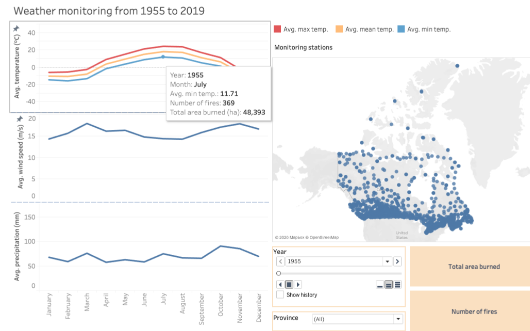



Fig. 41: Average temperature per month (tooltip)

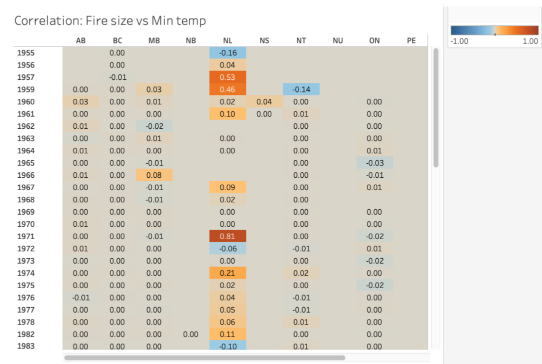



Fig. 42: Correlation between fire size and average minimum temperature

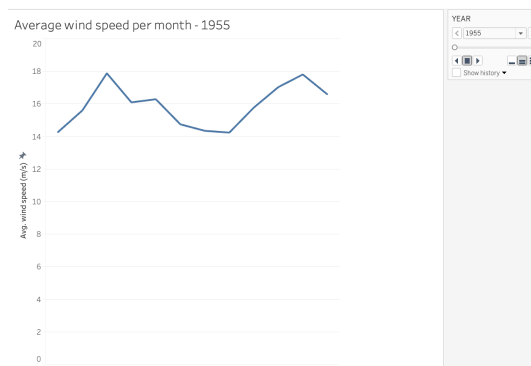



Fig. 43: Average wind speed per month

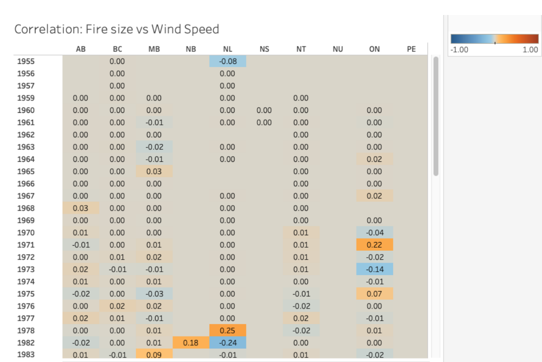
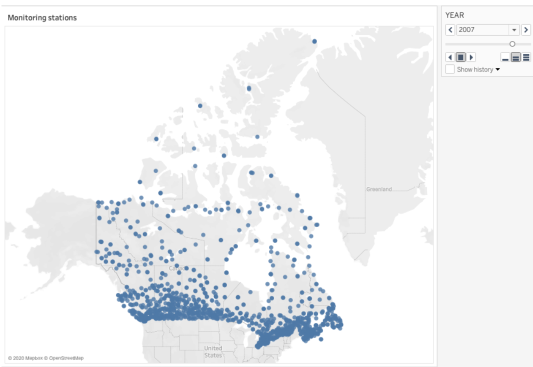
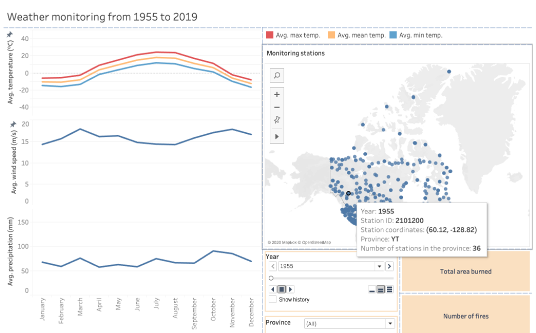



Fig. 44: Correlation between fire size and average wind speed

Design choice We chose a thematic map with points to represent each station (Fig. 45a). The map can be controlled using the year page filter and the province simple filter. Moreover, hovering over a particular point in the map displays a tooltip (Fig. 45b) containing the station ID, geographical coordinates, province abbreviation, and the total number of stations at the province for that year.




(a) Monitoring stations




(b) Monitoring stations (tooltip)

Fig. 45: Design choice for representing weather monitoring stations data

### 6.1.12 Weather Monitoring: Relationship with Wildfires

We decided to display information about the number of fires and the total area burned, derived from NFDB point data, in the same dashboard as the weather parameters to allow for quick referencing.

Design choice We chose a bar chart to encode both the number of fires and total area burned per month, as shown in Fig. 46. To avoid clutter, the charts are displayed in a tooltip upon hovering the desired label, as exemplified in Fig. 46a and in Fig. 46b.

### 6.1.13 Property Losses Due to Wildfires

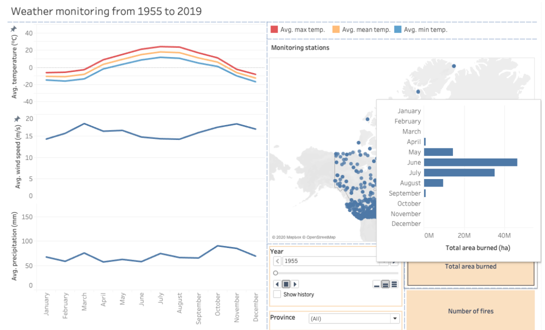
Wildfires directly impact the economy. To understand the effects of wildfires in terms of property losses, we visualized the property loss data.

Design choices considered

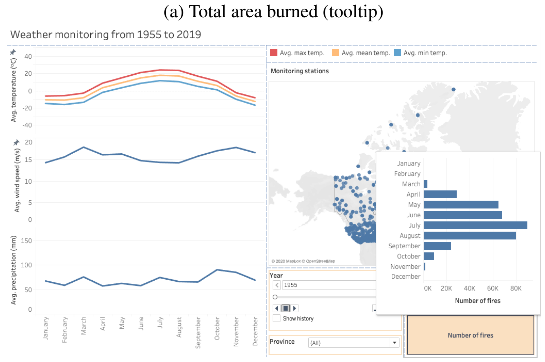
1. To get an overview of the property losses over the years, we plotted the dollar value against the years as a line graph as shown in Fig. 47. We call this graph as displaying reported property losses as the data is incomplete and has missing values at various levels of data.

   *Marks and Channels:*

   - Points connected by line connection marks encode the value of property loss in dollars.




(a) Total area burned (tooltip)




(b) Number of fires (tooltip)

Fig. 46: Design choices for representing weather monitoring stations data

2. We tried to plot the distribution of property losses across provinces. We plotted a bar chart as shown in Fig. 48.

   *Marks and Channels:*

   - The length of the bar encodes the value of propperty loss for a given ISO (province).
   - Color encodes the ISO.
   - Text annotation displays the actual value of property loss for provinces where the values are not zero.

   Even though this graph (Fig. 48) is useful and clear in terms of visualization, we decided not to pursue this further as we can see that for some provinces, data is completely missing. We do not know if the value was actually zero or whether it was due to values not being reported in the data. Thus, we do not consider this aspect in our analysis.

### 6.1.14 Wildland Protection Costs

To visualize the expenditures by the government towards wildfire mitigation efforts, we used the wildland protection costs data. This visualization should help analyze and guide further activities in the field.

Design choices considered

1. We plotted the number of fires and total fire expenditures, over the years, on the same graph using the idiom of superimposed line charts. We also decided to include trend lines for both of the quantitative attributes, number of fires and total fire expenditure. This graph, with the quantitative attributes on the vertical axis and the ordered variable year on the horizontal axis, is shown in Fig. 49.

   *Marks and Channels:*

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

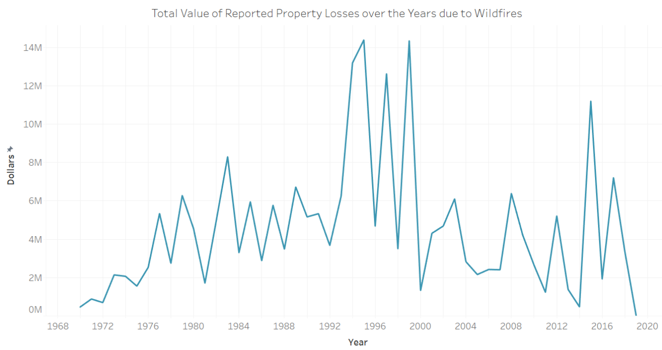



Fig. 47: Plotting the reported property losses due to wildfires over the years.

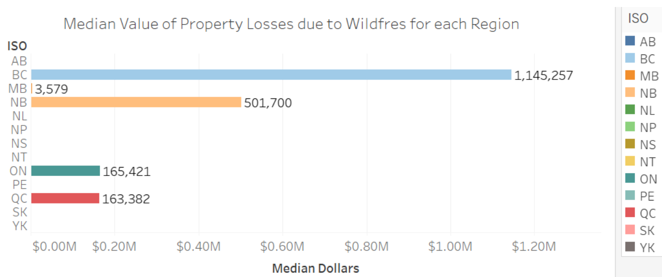



Fig. 48: Distribution of property losses across provinces of Canada.

- Points connected by line connection marks encode the total fire expenditure.
- Dashed line encodes the trend line. One for number of fires and one for total fire expenditure.
- Color encodes the quantitative attribute displayed.

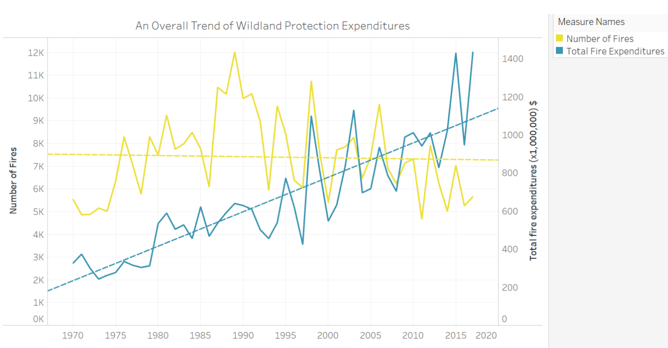



Fig. 49: Plotting the wildland protection costs and number of fires over the years as superimposed line charts.

This graph, while effective, puts some cognitive load on the user as understanding so many lines at a time is not very easy. To ease understanding of the graph, we considered another design choice as follows.

2. We changed the idiom from superimposed line charts to a combination of superimposed line and bar charts. This helps differentiate between the two quantitative attributes more quickly, and is shown in Fig. 50.

   *Marks and Channels:*

   - Points connected by line connection marks encode the number of fires.
   - Line marks (bar) in vertical position encodes the total fire expenditure.
   - Dashed line encodes the trend line. One for number of fires and one for total fire expenditure.
   - Horizontal spatial position channel separates the years.
   - Color encodes the quantitative attribute displayed.

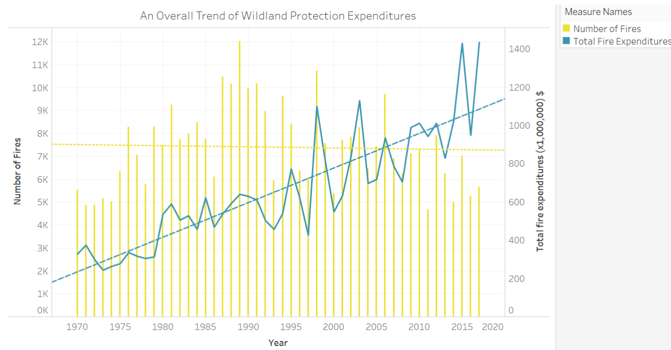



Fig. 50: Plotting the wildland protection costs and number of fires over the years as superimposed line chart and bar chart, respectively.

## 6.2 Current Tab: Visualizations and Design Choices

We focused 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. The overall design of this tab is two side-by-side maps that are both comprised of two superimposed geographical maps with current fire data elements. Legends and filters are available below the maps as well as text-based alerts and location-based AQHI status.

### 6.2.1 AQHI

Detailed AQHI is used from available hourly data within BC. We provide this feature so that users can view the current level of air quality metrics. This is also helpful in locating monitoring sites and finding values, names, and time updated associated with different locations.

#### Design choices considered

1. We plotted the categorical key attribute attribute AQHI readings connected by the monitoring sites similar locations. By making this connection, we used the Tableau generated latitude and longitude to generate the geographical map and plotted the AQHI sites by their provided location.

   *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 explored a couple ways to do this and what information is the most relevant. We aimed to provide an organized view that provides the most up-to-date information on location and AQHI first followed by the particulates. BC Data Catalogue provides a lot of information of each AQHI monitoring site and score shown in Fig. 51 and Fig. 1b.

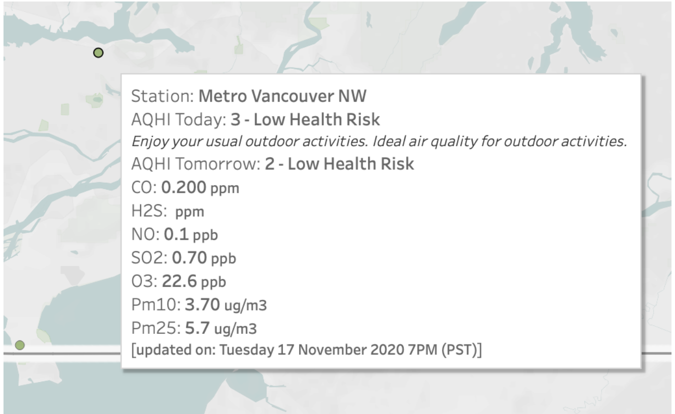



Fig. 51: Text based details on the tool-tip for the Current tab when users hover over a circle mark

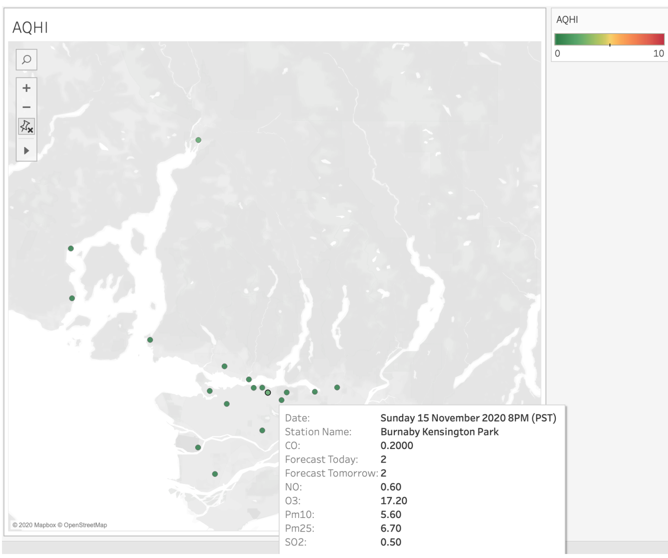



Fig. 52: British Columbia's AQHI data from gov.bc.ca hourly AQHI data

- Shown in the top right of Fig. 52, 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 stepped color coding.

2. Organization of the tool-tip was important for delivery of information. 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 considered what messages to include and decided on health risk level and recommendation for activity outdoors, as this is commonly what people see when looking for AQHI readings. While considering these factors, we have decided that things like time and date updated, station name and AQHI reading are essential to include so users have a reference for what data they are looking at, details shown in 52.

3. Color of the AQHI marks indicates level of health risk in the area: lower AQHI score is green, moderate is yellow, and red is not healthy to breathe for extended periods of time. The colors are stepped and diverging. This non linear color spectrum Fig. 52 chosen to show the possible in between AQHI readings that may happen.

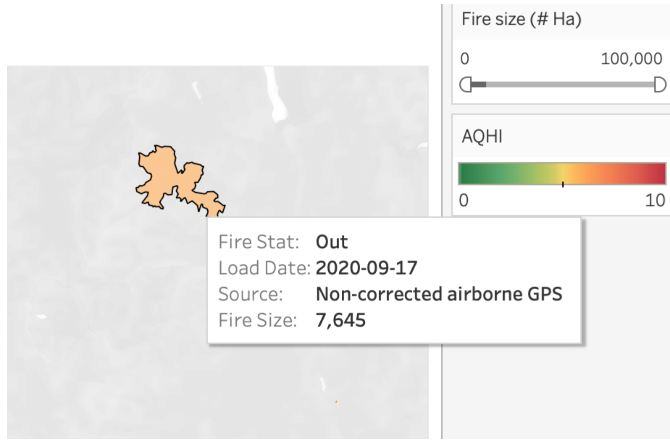



Fig. 53: Fire Perimeter is shown by the position of an area mark over the geographical map relative to its size in Hectares.

### 6.2.2 Fire Perimeters

We plot the current fire perimeters to locate fires and identify their relative size.

Design choices considered We use 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. We superimposed the fire perimeter area marks over the AQHI map to show fire size and proximity of monitoring sites. The idiom used here is cartographic layering. 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 use 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.

*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. 53.
- Visible fire perimeters can be filtered shown in the filter in the top right corner of Fig. 53. The user can select the range of viewable fires by size in Hectares.

### 6.2.3 Smoke Plumes

The task here is to locate areas that are affected by nearby fires as well as impacted areas over the last 24 hours. This data was collected from SmartFire 2.0 via FireSmoke.ca. [1]

Design choices considered

1. We plot the spatial position key attribute smoke area. Dynamic animated smoke can help show density as well as direction of the

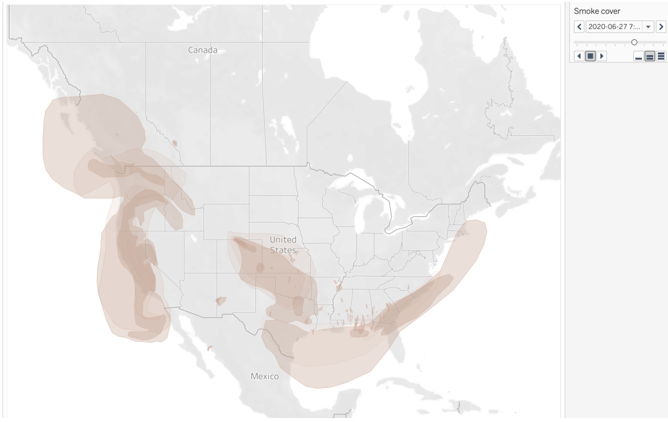



Fig. 54: Smoke cover is depicted over a geographical area. Relative area covered over map and luminance show how dense and how much area is smokey. Looped animation shows hourly smoke change.

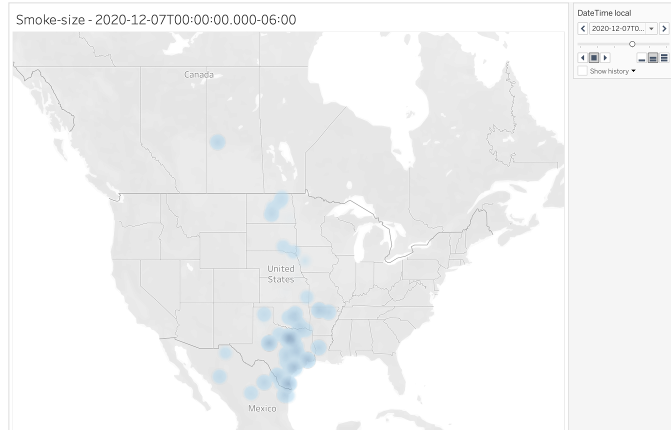



Fig. 55: One possible implementation of showing smoke area and density.

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 Fig. 54. We considered implementing this in one of two ways: the first design we considered was area marks of the same, medium to low opacity so when they are superimposed, the overlapping area that looks darker will communicate denser smoke. Another consideration was to use the location of the areas and provide size and opacity mark to communicate density in a particular area Fig. 55. The first approach (Fig. 54) was more straight forward to interpret and more suitable to animate for our intended purpose, since the size marks could be confusing for users to interpret as smoke coverage.

*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. A static instance is presented in Fig. 1b.
- 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.

2. As shown in Fig. 55, we considered implementing the smoke cover in a density map. This way the implementation would use live data, although we were not able to obtain data over the span of the past few days, only the current day. This eliminated the possibility of animation. Additionally, shape files of smoke coverage were unavailable, so we tested using size marks with different luminance to show density. This did not communicate the coverage as we had hoped, and we prioritized showing movement in the smoke through animation, therefore the area marks implementation was more communicative.

#### 6.2.4 Dashboard Design

We faced a design limitation when trying to superimpose more than two geographical map with Tableau. For this reason we were unable to provide a map that includes smoke area, AQHI sites, as well as fire perimeters. As shown in Figure 1b we implemented two side-by-side geographical maps. Left map superimposes the AQHI sites and fire area, right map superimposes smoke area and fire area. Given the limitations, we chose to split the maps this way to signal towards comparisons we wish the viewers to make; for example, by having smoke and fire area correlated, viewers are able to see how large a fire is and the smoke plumes that are dispersed because of it. This implementation proved to be an effective workaround given the limitations we faced. In the dashboard we also included legends, filters (as explained in following sections), and informational bulletins including alerts and warnings.

## 7 Implementation

In this section, we will discuss the main pipeline used for implementation, from data gathering to deploying.

### 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 [49] 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 disjoint 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. Our implementation in Tableau does not involve any scripting. We use and build upon the inherent features provided by Tableau. Most features come in the format of selections or drag and drop. Visualizations were customized by selection of relevant attributes, and using what Tableau calls "cards" for manipulating the level of detail and the appearance of the visualization. Features such as tooltips, marks, hover over details, annotations, colors, legends, filters, and pages for animation. Manual inputs or editing were performed for tasks like creating calculated fields or derived attributes. Inherent features particular to map charts such as zoom in and out, panning and selecting parts of the map were kept for all the geographical visualizations.

### 7.3 Milestones

The milestones were divided in a way that all team members have similar workloads. The individual contributions are enumerated in Table 7. An overall breakdown of the tasks, estimated timeline, and the updated actual timeline of work is shown in Table 8. Work on data processing and visualizations for the current tab was performed by Hannah and Preeti. Data processing and visualizations for the historical tab were performed by Roopal and Rubia. Merging of views and design decisions for final dashboards were collectively done by all group members.

Table 7: Contributions towards each milestone. Milestones and number of hours.

| | Number of hours | | | |
|---|---|---|---|---|
| **Milestone** | Hannah | Preeti | Roopal | Rubia |
| Pitch | 3 | 3 | 9 | 3 |
| Pre-proposal meeting | 3 | 3 | 3 | 3 |
| Proposal | 2.5 | 2.5 | 2.5 | 2.5 |
| Data processing | 8 | 8 | 8 | 9 |
| Implementation Draft I | 7 | 7 | 10 | 4 |
| Update Report | 13 | 9 | 17 | 11 |
| Meeting time | 8 | 8 | 8 | 8 |
| Peer project report | 2 | 2 | 2 | 2 |
| Updates to data | 7 | 5 | 5 | 4 |
| Further implementation | 6 | 6 | 12 | 12 |
| Dashboard views, website | 8 | 9 | 11 | 5 |
| Meetings after update | 12 | 12 | 12 | 12 |
| Final Presentation | 5 | 6 | 5 | 5 |
| Final Report | 15 | 14 | 19 | 12 |

## 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 could help users analyze historical wildfires in the context of climate and economic data.

### 8.1 Usage Scenarios

We list usage scenarios of possible end users here.

#### 8.1.1 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.

#### 8.1.2 Viewing current fires compared to historical fires.

Another feature of the historical tab will be viewing an superimposed map of historical fires over causes. The user may come here to answer questions such as: Was there a fire here recently? What was its cause? Is this area I want to go backpacking burning or already burned? They will be able to use the filters to view the historical information and filter by year and cause.

#### 8.1.3 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.

### 8.2 Merging Views

After considering the multiple design choices of visualizations, and historical and current aspects of wildfires, we combined the related visualizations into Tableau dashboards and stories. Since the amount of information is large, we decided to split the views into three major parts: current wildfires, historical wildfires and the data. To cater to our goal of presenting information in one place and making it available to all types of users, we created a public web interface. We now first talk about the collective dashboards and stories built, the interactivity provided to users, and the results of analysis in terms of interpretations that can be made from each dashboard. We then describe the structure of the web interface and how these dashboards become components of the different pages.

### 8.3 Historical Dashboards

We had initially proposed to create a single dashboard for all the historical charts. However, since the number of visualizations under consideration is large, we decided to create multiple dashboards to depict results from different factors affected by wildfires. Also, trying to put together all charts in one dashboard placed space constraints and caused a cluttered view as seen in Fig. 56. While it was still possible to include all charts in a single dashboards by using techniques like navigating through links and creating hover-over links to display charts, it would have defied the purpose of providing all information in a view at a single place. We thus preferred using multiple dashboards. These historical dashboards contribute towards completing the requirement R2.

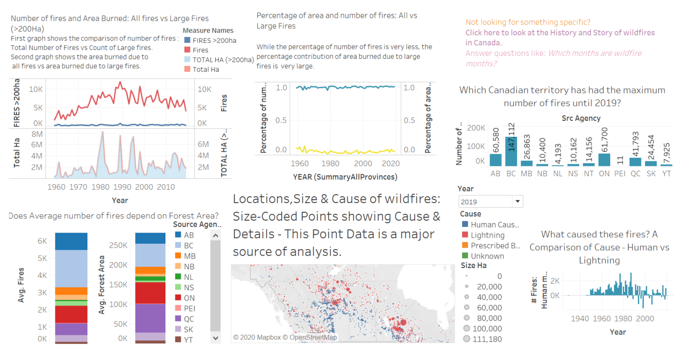



Fig. 56: A cluttered historical dashboard is challenging to analyze and can be visually overloading. Instead, multiple dashboards splitting into different sections is preferred.

#### 8.3.1 Locations and cause of fires

The visualization created from the shape file of wildfire polygon data is placed under one dashboard. The reason for placing this visualization as a standalone dashboard is that loading the large file is time-consuming, and combining it with charts from other datasets would further increase display and interactivity overhead. Keeping it in a single dashboard quickly loads the map. This dashboard is shown in Fig. 57. Users can use the multiple value list dropdown to view fires from selected years.

*Interpretation:* Viewing the map and changing the years selected helps understand and view the regions in Canada where wildfires have occurred. This visualization helps answer custom questions such as “Did a region have any fires in selected years?”, “Where were fires located in a given year?” and “View all fires so far in Canada.”.

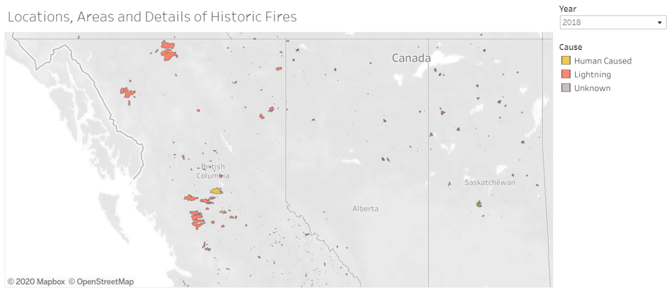



Fig. 57: Historical dashboard for locations and cause of fires.

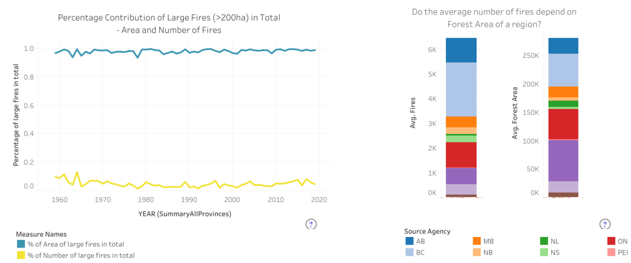



Fig. 59: Historical dashboard for factors related to number of fires.

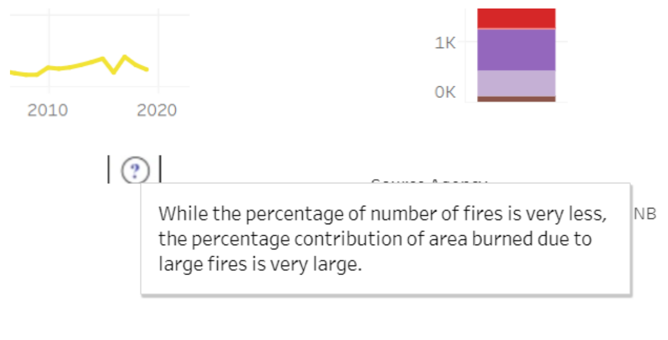



Fig. 60: Hover over help interactivity in the historical dashboard for factors related to number of fires.

### 8.3.2 Overview of trends and distributions

To provide an overview of the most basic trends and distributions related to wildfires, we put charts for annual number of fires, distribution of number of fires across provinces, identification of wildfire months, and identification of most often cause of fire. This dashboard is shown in Fig. 58.

*Interpretation:* The top-left graph shows the annual number of fires. The number of fires shows an increasing trend up to the year 1989, after which we see a downward trend. Overall, the number of fires has a decreasing trend. The provincial distribution shown in the top right graph reflects that British Columbia has had the highest number of wildfires until the year 2019. The bottom-left graph identifies the fire season, with the core fire months being May-August, and the bottom-right graph suggests the humans are more often a cause for wildfires against natural causes like lightning.

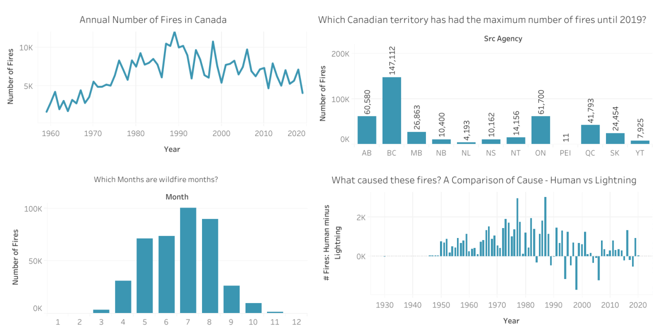



Fig. 58: Historical dashboard for overview of trends and distributions.

### 8.3.3 Dependencies of number of fires

We put graphs that analyze the factors related to number fires in the dashboard seen in Fig. 59. Since these graphs may not be very easy to understand for everyone, we provided additional interactive help information buttons represented by a question mark and shown in Fig. 60. Hovering over to the help button provides the information about the graphs. The stacked bar charts are interactive. By selecting a province, the regions in both the bar charts for that province are highlighted and other provinces are dulled. An example of this interactivity can be seen in Fig. 61.

*Interpretation:* From the charts in the dashboards, we can conclude the following: While the number of large fires (fires that cause a burned area of 200 ha or more) is small, the area burned by them makes up for a large proportion of the total area burned by all fires. Also, there is no direct relationship between the forest area of a province and the number of fires. For instance, Quebec has the largest forest area, but the number of fires is not the largest.

### 8.3.4 Effect on air quality

The graphs that analyze the pollutant PM2.5 become a part of this section. For setting up dashboards that are easy on the eye, we put boxplot charts in one dashboard and choropleth maps in another. However, both these dashboards are part of the same section.

The dashboard in Fig. 62 shows the monthly PM2.5 values for regions as well as air zones of BC. Interactivity is provided for highlighting a particular month. As seen in Fig. 63, selecting a month highlights points for that month in both of the boxplots while the points for other months are faded. We include regions as they provide more detail and more understandable. Air zones are included as the choropleth maps in the following dashboard (Fig. 64) makes use of air zone regions. Selecting a year from the dropdown menu in this dashboards displays the values for each air zone of British Columbia.

*Interpretation:* Looking at the boxplots, it can be seen that for the majority of areas, the PM2.5 levels are at a high during August, a core wildfire month. From the comparison of choropleth maps showing the pollutant values for core months and non-core months. It is evident that the pollutant PM2.5 has higher levels in the months of May-August as compared to other months. The values for PM2.5 levels were extracted from stations where data was available. Not all stations in every air zones are available in the historical data.

### 8.3.5 Weather monitoring

While the visualizations from the AHCCD were many, we decided to combine the most important and crucial charts in the dashboard as seen in Fig. 65. Interactivity such as selecting a year from the dropdown menu, animating changes over the years using a play forward button, and selecting a particular province from the dropdown are available. Zooming and panning features are also available for the geographic map. Bar charts showing information about number of fires and area burned are also provided as hover over buttons to supplement the climate data and to aid relating the information directly with wildfires. We use the hover button to provide this information on demand as seen in Fig. 66.

*Interpretation:* The general patterns over the years reflect that the average temperature is higher in the months June-August which suggests that higher temperature and wildfires go hand in hand. This is also because July and August are usually summer months across most provinces. A lower wind speed is also seen in these months. The data for precipitation shows much lower rainfall levels for provinces like BC

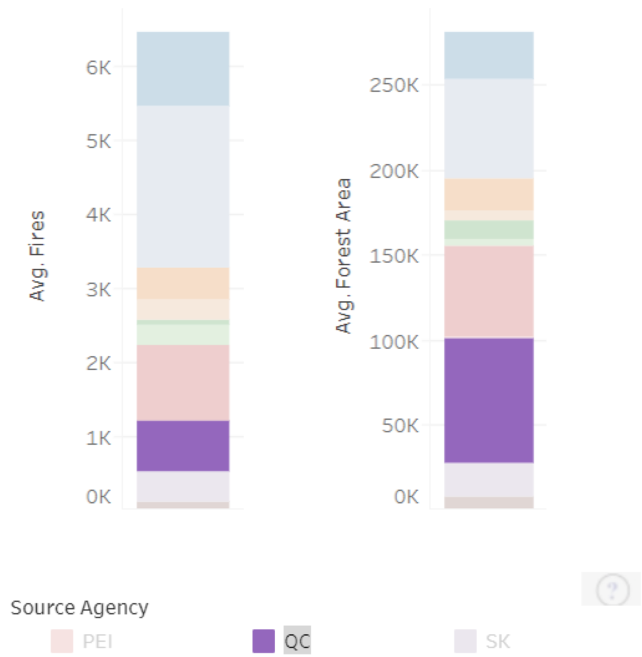



Fig. 61: Highlighting interactivity in the historical dashboard for factors related to number of fires.

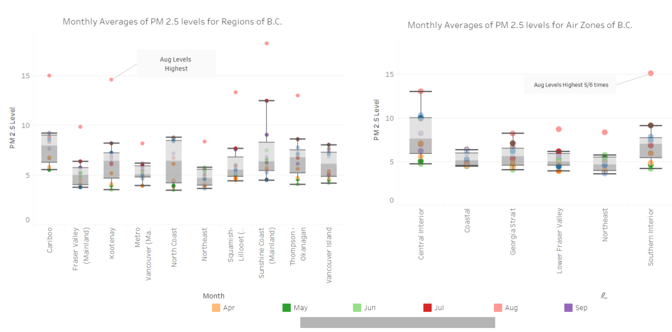



Fig. 62: Historical dashboard for air quality boxplots.

in the months May-August. The official weather monitoring stations used to capture the data over the years can be viewed on the map to understand the data.

#### 8.3.6 Monetary effects

The charts for property losses and wildland protection expenditures were put together in one dashboard as seen in Fig. 67.

*Interpretation:* As wildfires started to occur more often in earlier years, government spending towards wildland protection efforts saw an increase. Even though we now have a decreasing number of fires over some recent years, government spending shows an increasing trend, as shown in the graph on the right. This correspondingly reflects that wildland protection methods are effective and the reduction in number of fires in the overall trend is a consequence of protection expenditures applied.

### 8.4 Historical story

In an attempt to provide a summarized view of all factors and to cater to users who might not be looking for anything specific, we provided a short story by putting together the dashboards together in a sequence. This helps to provide an overview for users who just want to have a quick look. This Tableau story is shown in Fig. 68. The requirement R2 is further supplemented by this story.

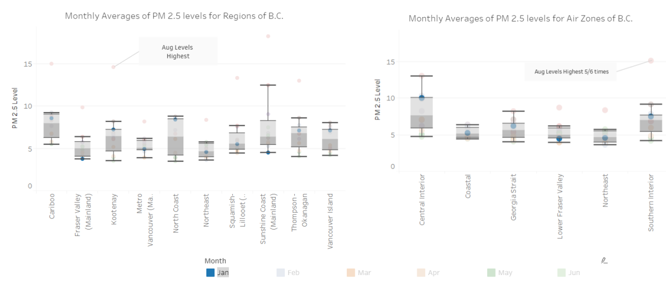



Fig. 63: Highlighting interactivity in the historical dashboard for air quality boxplots.

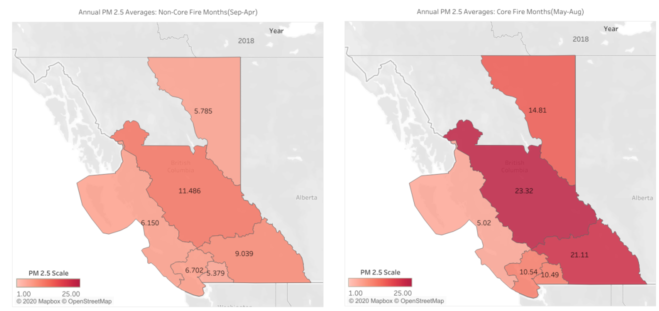



Fig. 64: Historical dashboards for choropleth maps comparing air quality between core fire months and non-core fire months.

### 8.5 Current Dashboard

As mentioned in the design decisions considered of the current dashboard, we originally intended on having the current tab show three maps superimposed on one another: AQHI sites, fire perimeters, and smoke area. This would have ideally allowed users to make inferences on the correlations between fires, air quality, and smoke density in particular areas. Fire alerts and location based air quality readings would have supplemented this geographical data well to provide an up-to-date, user geared experience of the current tab. By splitting up the maps, we believe this is still accomplished although users may have to do a bit more inferring on their own between the right and left map views. We were able to implement animation of the smoke areas to show the movement over time and filters for different fire sizes to help communicate current fire changes. This current dashboard contributes towards completing the requirement R3.

### 8.6 Data Dashboards

Not all visualizations are meant for reaching a result for analysis. Some visualizations are better suited for just understanding the data and not for their display per say, while some are helpful to understand avail-

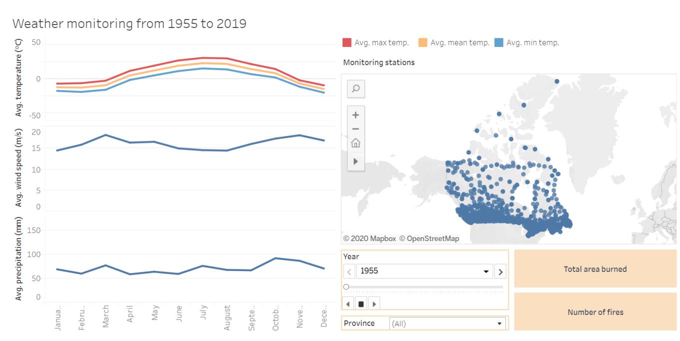



Fig. 65: Historical dashboard for weather monitoring and climate.

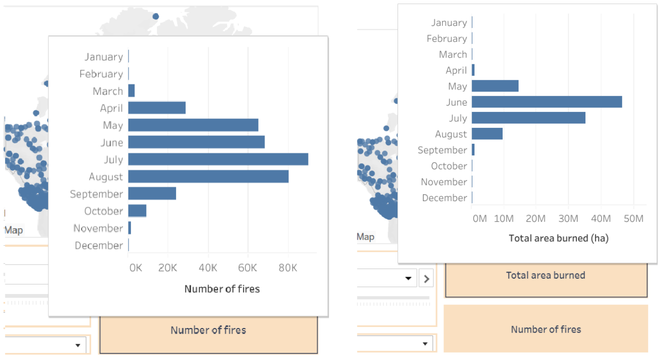



Fig. 66: Hovering over the buttons for viewing bar charts in the weather monitoring dashboard.

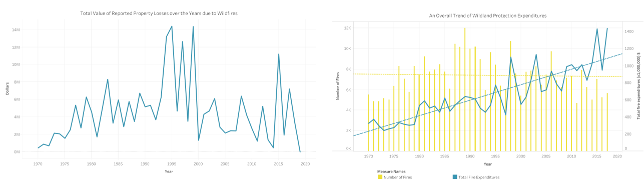


Fig. 67: Historical dashboard for monetary effects.

ability of data itself. We decided to create a data pane just to provide visualizations details information about the data, not its analysis. Some of these visualizations were part of design choices that did not become the final choice.

### 8.6.1 Wildfire Point Data

While we selected the dashboard with shape files as shown in Fig. 57 to show the fire locations and causes, we wanted to keep the point data visualization as it is the basis of the majority of the analysis. Also, there are some differences in the availability of data between the wildfire point data and the wildfire polygon data. Thus, we used the dashboard in Fig. 69 to represent the point data. This is just provided as supplementary information to the data sources used and to show points of wildfires. This is by no means an analysis graph as it is not thematic.

### 8.6.2 Air quality measurement stations

Since all measurement stations for air quality in air zones of BC are not available in our data source, we visualized the locations in our data to clarify the source of the analysis. This is shown in Fig. 70.

### 8.6.3 Availability of data across air zones

The choropleth maps that we used previously compare the air quality between fire and non-fire months. The data is not always available for all years. We decided to animate the availability of data for air zones across years and provide it as a dashboard as shown in Fig. 71. Using the play forward button, users can dynamically view the changing data availability as an animation. An example of some instances can be seen in Fig. 72.

## 8.7 The Web Interface: Firest

Using the dashboards from the current and historical tabs, the results of historical analysis, and descriptions of interactivity, a web interface "Firest" was created. The interface was implemented in HTML and CSS, in the format of a website, publicly available at https://firest547.github.io/. We created web pages to include content from the historical and current dashboards created. The dashboards were saved to Tableau public and the views were embedded into the web pages directly. Further, a data page providing supplementary data availability dashboards and links to data sources is provided. The website additionally contains the standard landing page and authors page.

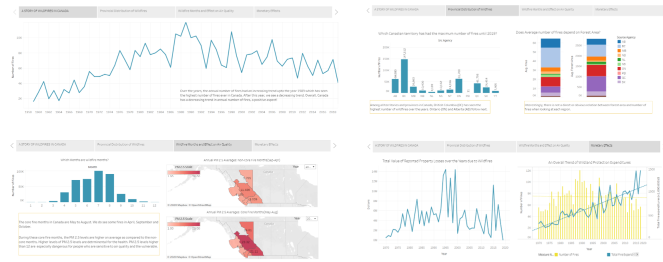


Fig. 68: A story of the history of wildfires in Canada.

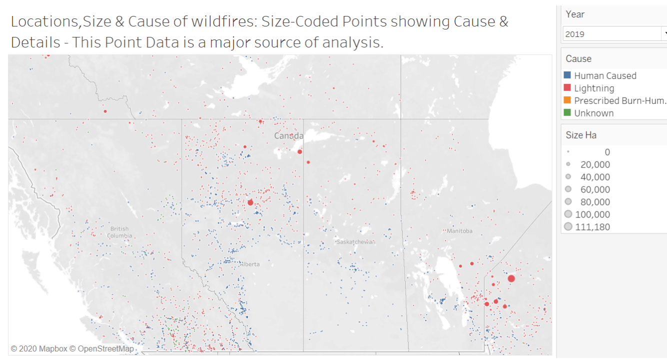



Fig. 69: Wildfire point data visualization. Acts as supplement to data source information.

This website fulfills the requirement R1 by providing all information in one place.

## 9 Discussion and Future Work

This project brings together a comprehensive visualization of wildfires and related parameters. The current dashboard shows the present state of affairs and the historical dashboard presents a thorough analysis of relevant topics stemming from wildfire data. These two segments are merged together and published publicly on the web. Within the website, several visualization idioms are organized thematically; this makes them convenient for exploration and targeted search based usage. The website format is easy to use and intuitive for novice users, with no training required to use the interface. Although the wildfire data itself does not offer evident interpretations, our visualizations focus on bringing discernible relationships among various attributes.

Tableau [49], the tool we used, helped us develop these visualizations. Tableau is sleek when it comes to relating and joining data, and for creating new calculations and derived attributes on the go. Although Tableau is a powerful tool, it has some limitations in terms of representing data. For our project, we struggled while merging multiple views on the geographical map. Due to these limitations, the information for air quality and smoke had to be separated into two separate views in our current dashboard. Moreover, since Tableau Public does not allow publication of live data sources like Google sheets, our current dashboard depends on manual updates. We acknowledge that Tableau helped us with the quick start, but the steep learning curve was difficult to overcome and we ended up spending considerable time on learning the capabilities of the tool.

We worked with governmental wildfire data sources. As we progressed with data gathering and cleaning, we realized that these data sources are inconsistent; this made it challenging to create fully integrated visualizations. We only have historical data available from the year 1955 and oftentimes, the collected data is dependent on monitoring sites which often vary over the years. This inconsistency may lead to misleading comparisons. The current data also has several variations across provinces such as – different data format, collected measures, and naming conventions. We had to scope down our current tab to show data for one of the provinces for which most of the information

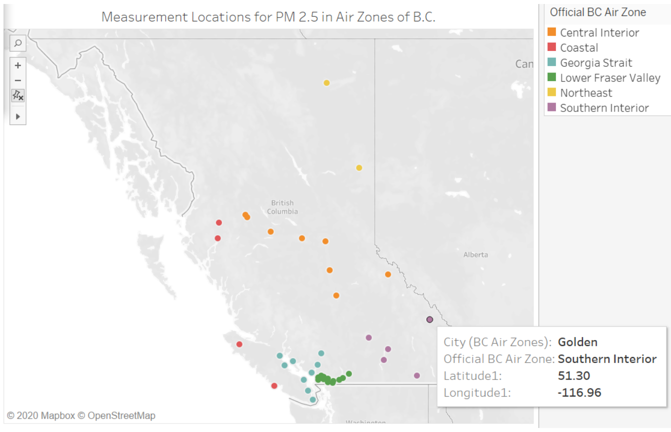



Fig. 70: Air quality measurement stations available in data source.

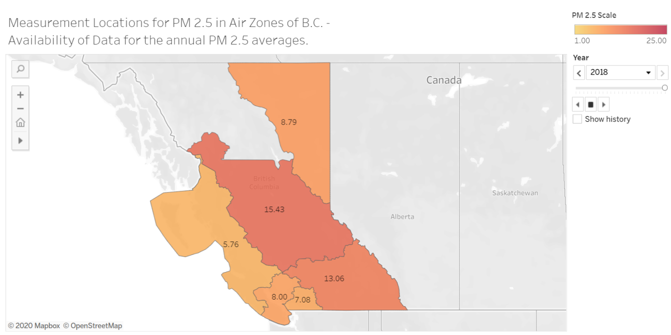



Fig. 71: Air quality measurement stations available in data source.

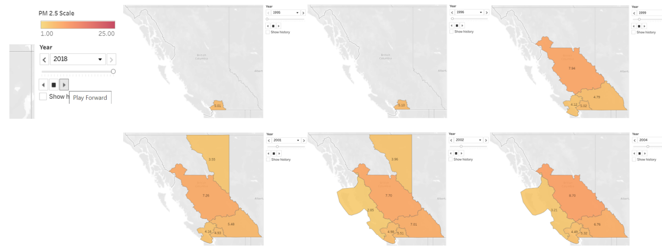


Fig. 72: Some instances of animating the air zone data availability.

was available. We were able to set up a live data scraping pipeline for current dashboard using Google Sheets, but due to the frequent link inactivity on the data server side of the data catalogs, we often faced interruptions in our work flow.

Overall, the major lessons we learned are – (a) aggregating data from different resources is not straight forward due to inconsistencies; (b) it takes considerable time and efforts to clean and merge the data sources; and (c) tableau is not as flexible as we initially assumed and often required brute force tweaking for data manipulation and visualization.

In the present stage, considering the geographical scope of Canada, our project still needs to have an overall integration of wildfire and related data from various provinces. Factors such as differentiating the type of forest area burned based on land type, type of forest is also scope we have not considered so far. Dependencies on locations and geographical characteristics such as elevation data will add more depth to the analysis results. This is something we would want to add to our analysis in the future.

We also need to have a reliable source for live wildfire data which can be accessed directly by the current dashboard. Data personalization using live location of user might prove helpful as well. Developing a better integration pipeline by taking into account the individual data inconsistencies might help us achieve the goal. We can also add several other elements like live evacuation site information and location specific real-time warnings.

In this project, we prioritized functionality over aesthetics. More dynamic interactions and animations can be implemented to make the graphs more visually appealing and inviting. Styles similar to Tableau's storyboard narration can be used to present an interactive overview of current and historical wildfires. On the software side, it might help to move to a more flexible platform that allows for live data integration, and unconstrained data manipulations and visualizations. In this respect, using open source tool such as D3 [9] or Plotly Dash [43] can prove beneficial.

## 10 Conclusions

Wildfires burn millions of acres of land every year and severely impact peoples livelihood. Apart from causing loss of life and property damage, wildfires also have an impact environmental factors like air quality, visibility, temperature, precipitation, and wind speed. Overall, these effects are often intertwined and the effect is two-way. While factors such as high temperature may lead to wildfires, occurrence of wildfires further leads to higher temperature. We identified the need for a comprehensive visualization of wildfire and related data such as air quality, temperature, and smoke. In this respect, we present Firest – a Tableau-based visualization of current and historical wildfires; published on the web for open access. For the scope of the project, we presented the visualizations for Canadian provinces. Unlike previously available visualizations, Firest aims to bring together not only wildfire data but also wildfire related parameters at one place. Another important aspect of our work is visualizing not only current state of wildfires in Canada, but also reflecting back on the historical data, analyzing it, and presenting a bigger picture.

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Table 8: Milestones and task breakdown.

| **Milestone**<br>Task Breakdown | **Estimated hours** (per person) | **Actual Hours** (per person average) | **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 | Hannah, Preeti |
| First draft of Historical tab in Tableau (Design choices, Analysis) | 10 | 10 | Nov 13 | Nov 14 | Roopal, Rubia |
| **Update Report** | | | | | |
| Writing and Modifying report per feedback | 8 | 13 | Nov 16 | Nov 17 | Everyone |
| Meeting Times | - | 5.5 | Frequent | Frequent | Everyone |
| **Peer project report** | | | | | |
| Read peer update report, prepare feedback | 2 | 2 | Nov 19 | Nov 19 | Everyone |
| **Refine implementation from first draft** | | | | | |
| Add charts for temperature, AQI, economy data | 8 | 14 | Nov 27 | Dec 1 | Roopal, Rubia |
| Add smoke data, real-time data, notifications | 8 | 13 | Nov 27 | Dec 1 | Hannah, Preeti |
| Merge views, dashboard views, website | 6 | 11 | Dec 2 | Dec 8 | Everyone |
| **Meetings after update** | | | | | |
| Finalize report | - | 12 | Recurrent | Recurrent | Everyone |
| **Final Presentation** | | | | | |
| Finalize demo, prepare and rehearse presentation | 4 | 5 | Dec 9 | Dec 9 | Everyone |
| **Final Report** | | | | | |
| Finalize report | 10 | 15 | Dec 13 | Dec 14 | Everyone |