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

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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 it's correlation with climate change, for e.g., air quality index, smoke map, weather patterns drawn from historical data. This project aims to integrate multiple variables of interest regarding wildfires in one dashboard, facilitating access to wildfire related information. The scope is currently limited to Canada.

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 wildland fires have varied dramatically over time and space, largely due to the dynamic consequences of climate change and climate instability [1]. 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 [2]. 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 [3]. 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 [4]. Analysis of wildfire data often helps in understanding the patterns of wildfires to try and minimize their risk.

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

Additionally, current examples of wildfire visualizations do not provide the historical data to help grasp the climate impact of the fire season. Each year wildfires increase in size and frequency, but without the direct comparison of data it is hard to understand the impacts they have over the course of years. This problem could be mediated by visualizing historical datasets presenting the cause-effect situation in case of wildfires. We know that factors like climate change cause more severe wildfires [1], 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.

2. RELATED WORK

One of the national portals for viewing information about wildfires is the Canadian Wildland Fire Information System (CWFIS) provided by the Government of Canada [5]. This resource provides various dataset, such as fire weather maps, fire behaviour maps and fire M3 hotspots as shown in Figure 1. According to information available in this system, the fire weather maps visualize the fire danger which is a relative index of ease of vegetation ignition, difficulty of fire control and extent of fire damage. The fire behaviour maps use the head fire intensity (HFI) which is the predicted intensity, or energy output, of the fire at the front or head of the fire. Fire M3 plot hotspots, that is, a pixel with a high infrared intensity satellite image, suggesting a heat source. It may represent a single fire or may represent a larger fire as one of many hotspots. As an initiative of the Canada Centre for Remote Sensing and the Canadian Forest Service, the Fire Monitoring, Mapping, and Modeling Framework (Fire M3) began operations in 1998 [5]. 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.

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 [6]. This resource combines three key components of fire and smoke data as seen in Figure 2. The AirNow map utilizes multiple marks and channels to communicate location conditions. To encode

AQI, and monitor type, AirNow uses different colored marks to indicate the AQI and shape of mark to indicate whether the AQI monitor is permanent, temporary, or low-cost. The smoke plumes are shown as an area mark of varying luminance to show smoke density over a particular geographical area. Lastly, shape marks are used to show the location and size of a fire. Other geographical locations have similar maps that provide AQI information. For example, an Australian AQI map called MyFireWatch shows a map with only AQI reports and location of sites [7].

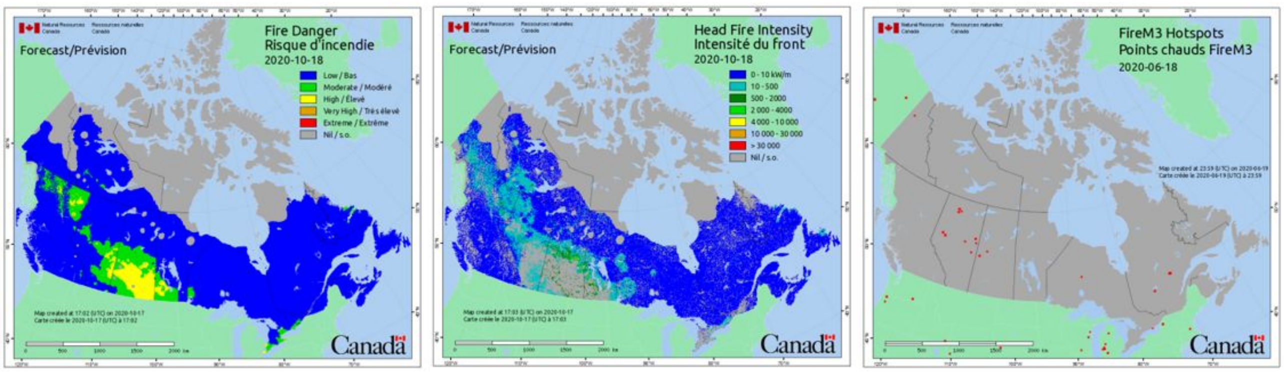


Figure 1. *Types of maps available in the Canadian Wildland Fire Information System. Left: Fire weather map, Middle: Fire behaviour map, Right: Fire M3 hotspots.*

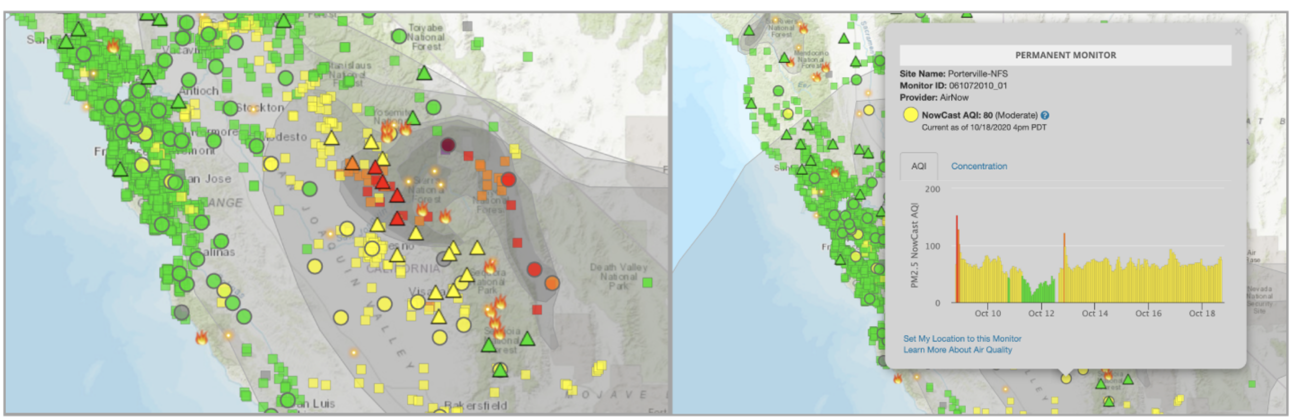


Figure 2. *AirNow Fire and Smoke interactive map. Left: view of the smoke density, fire location, and AQI. Right: by clicking one of the AQI sites, an information box provides relevant information to that particular AQI site location.*

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 [8] shown in Figure 3. This map communicates how big a fire is through a spatial representation (in total hectares) using area marks over a geographical map. This map is unique as it allows users to visualize overlayed BC data made available by the British Columbia Data Catalogue. Similar implementations of a perimeter map have been made such as Cal Gov's perimeter map that shows fire perimeters and their containment status on fires within the state of California [9]. Additionally there have been reports of Google implementing a fire perimeter map as a part of their Google Maps application, providing even more resource for emergency data [10].

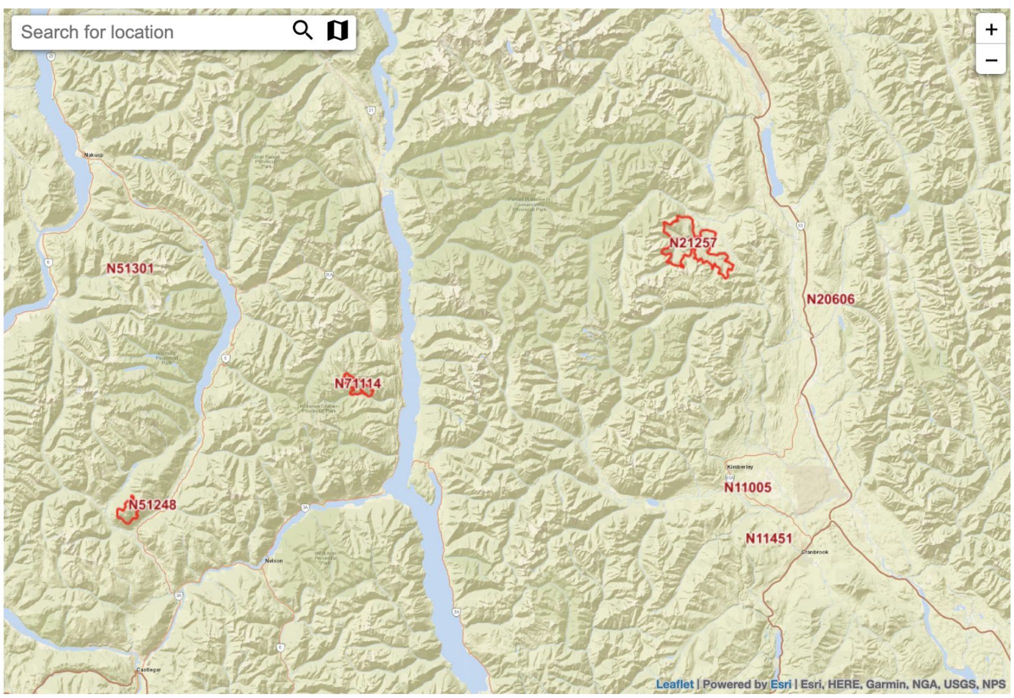


Figure 3. *Current fire perimeters outlined in red and provided by BC Wildfire Service on the BC Data Catalogue. Fires are coded with their fire number in red text.*

Another tool worth mentioning is the Firemap [11], developed by WIFIRE Lab researchers, at the University of California, San Diego. The Firemap provides access to information on several different data sources, including fire perimeter, smoke, weather conditions, and real-time fire forecasting. Although the tool encompasses many of the concepts suggested for the solution in this proposal, the data displayed is limited to United States territory. Figure 4 exemplifies Firemap's interface.

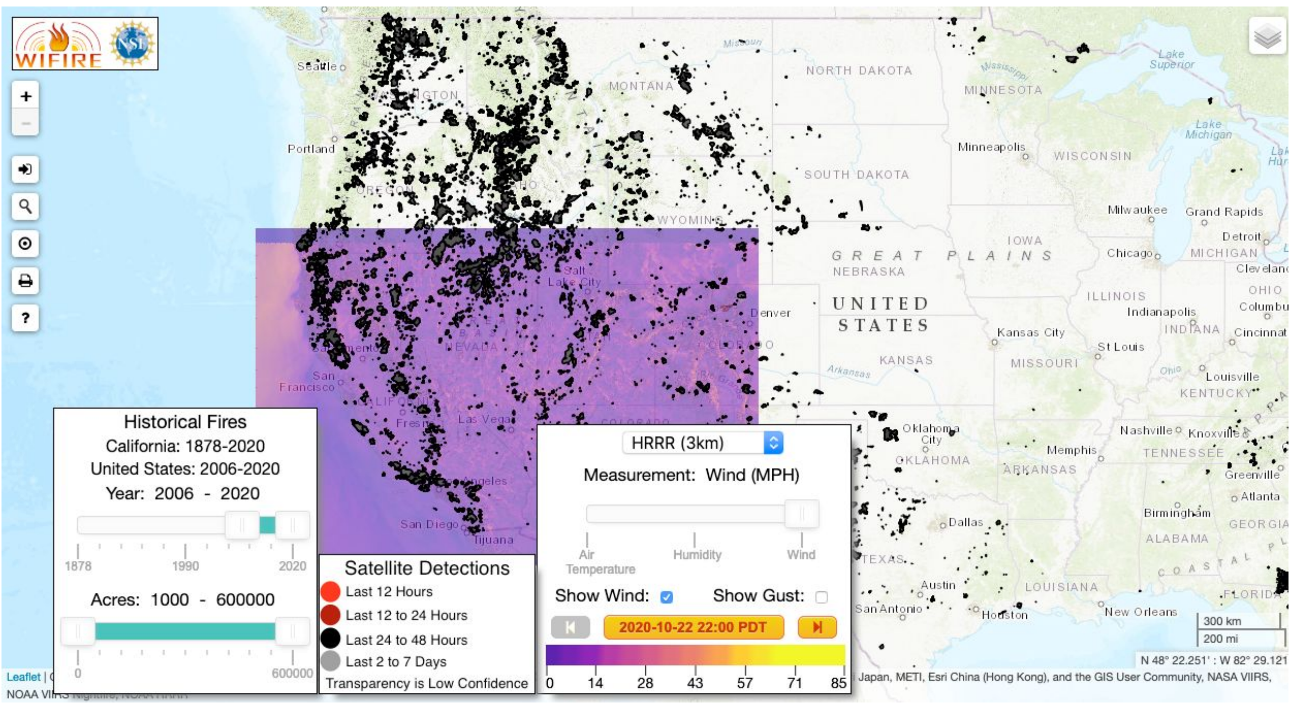


Figure 4. *Different views provided by Firemap, designed by researchers at the University of California, San Diego. Historical fires are coded in black, while the weather forecast is represented in the highlighted square region.*

3. TASK ABSTRACTION

3.2.1 Who

We as designers will make design choices. However, these design choices will be made keeping our potential users into consideration.

3.2.2 Actions

- **Analyze**
  - *Analyze*: We intend to use the process of designing Firest as an opportunity to explore factors that are affected by wildfires. This will be done by analyzing historical datasets providing information about wildfire locations, their extent, weather data among others.
  - *Consume*: As described in the implementation in the following section, our visualization also includes a current view which is meant completely for end-users' consumption. Our end users may include local residents, campers, and the general audience.
- **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.

- **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*: Comparison of extent of effects of wildfires over multiple regions will be visible on the map. For comparison of impacts of wildfires through an historical view, graphs and charts will be available. Maps with tooltips to display detailed information about specific data points will also be available.
  - *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, charts showing summary information will be available. If they want to look at details about a specific impact, detailed graphs will be provided by interacting with the visualization and selecting features they want to view.

3.2.3 Targets

- **Trends**

Once we visualize all data, we may come across certain regions that reflect some trend in occurrence of wildfires, for example, yearly or other historical trends. We wish to bring out these trends and highlight them in visualization.

- **Attributes**

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.

4. DATA

4.1 What: Data Abstraction

We have identified several Canadian data sources for wildfires and air quality index. As per our task we require two types of dataset---tabular and spatial. Spatial data will assist us to plot geotagged items which is necessary as per our task. Tabular data that we acquired can be used as it as or manipulated for obtaining derived attributes as needed. The attributes in tabular data are mostly categorical or ordered. Currently we are only scoping for a static dataset of particular year range. It may be expanded to dynamic data if needed. We haven't selected a year range window for historical data as we are still compiling our data sources.

4.2 Data Sources

We collected data sources for information on current and historical wildfire, weather, climate, and air quality index data. We found that current and historical wildfire data for BC, Alberta provinces are systematically organized and compiled and can be used directly. Both shape files and csv files are available. Although the data for weather [12], climate [13] and air quality index [14], [15] are scattered based on the data sampling stations and need to be accumulated. We only found csv files for these data sources. We will be sampling these data resources in the coming weeks.

We discuss major data sources in the Appendix. As an extension we are also looking at the economic impact of wildfires and found historical data of the amount spent on handling wildfires over the course of years [16]. We haven't incorporated this data source in our implementation discussion yet but we are planning to explore more information.

5. SOLUTION

We will aim to provide a combined data map (within Canada) of wildfire emergency and historical data. This data visualization will encompass air quality parameters, fire perimeter, and historical climate data related to wildfires.

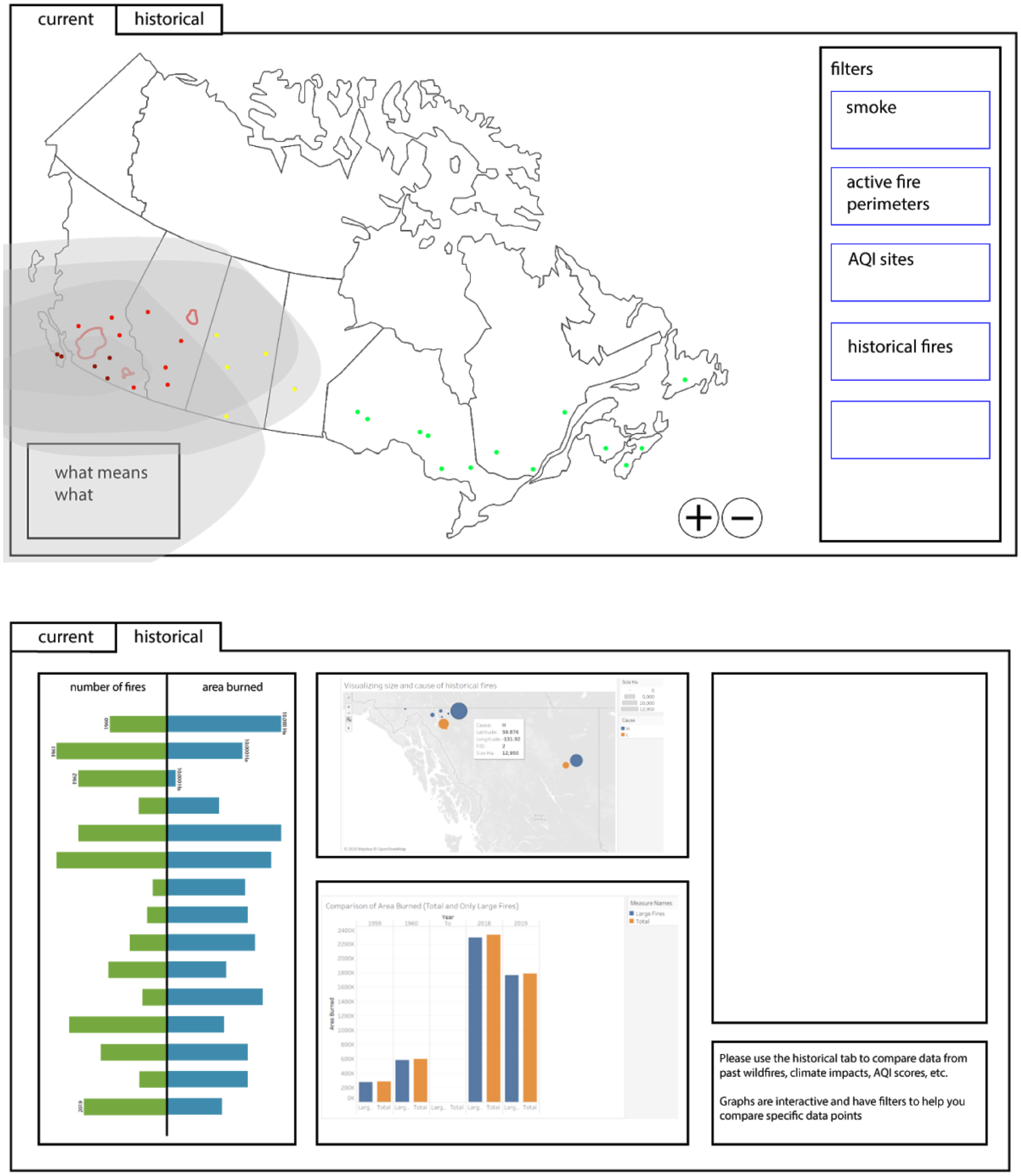


Figure 5. *Mock-up of Firest, the interactive wildfire resource. Above. Current tab of Firest, depicting superimposed relevant wildfire information. Bottom. Historical tab of Firest, depicting comparisons of historical wildfire and climate data.*

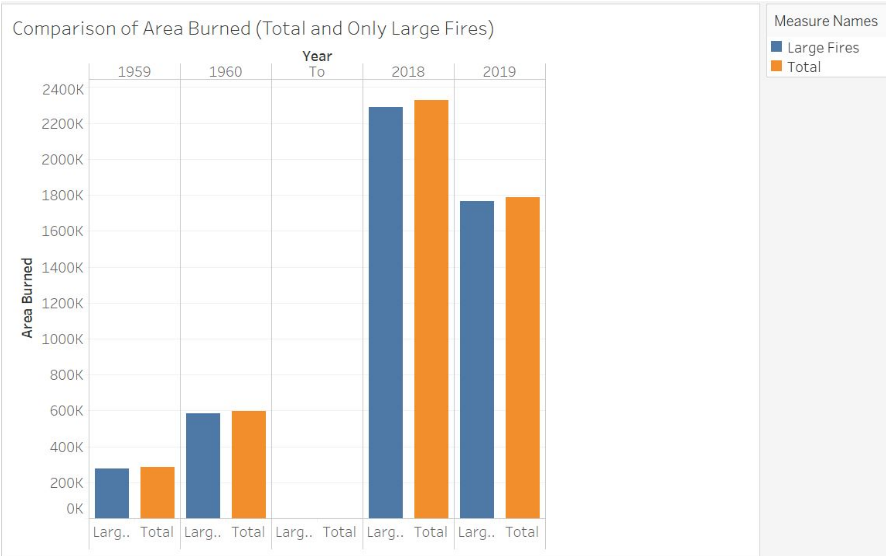
5.1 Implementation (proposed)

We will use Tableau[1] and Python (e.g. dash[2]) through the use of TabPy[3] to implement our geographical map visualization. Our scope will be within Canada, and primarily focused within British Columbia and Alberta as these provinces have the most fires, but this scope will be revisited as we continue to implement our interactive map. We hope to widen our scope to encompass current data reports across North, Central, and South Americas if possible. Our implementation will be in a Tableau dashboard format with one *current* tab and one *historical* tab as shown in Figure 5.

Current. The *current* tab will encompass all current wildfire data such as smoke, AQI, and fire perimeters. All features of the *current* tab will be shown on a geographical map. Smoke will be an area mark of varying luminance to show an approximation of smoke plume size and density. AQI will be shown similarly to current approaches by providing a colored shape mark of varying color to indicate AQI rating and shape to indicate a permanent, temporary, or low cost scanning site. The fire perimeters will be an area mark of the approximated perimeters of the active fires. The above image in Figure 5 depicts a mock-up of the *current* tab when selected. Filters on the right hand side will provide options to make data types viewable.

Historical. The *historical* tab will indicate the historical climate impacts of wildfires. This tab will also be a dashboard view. By allowing for multiple comparisons and options for geographic historical data and running bar graphs to show change over time, the *historical* tab will provide many areas of relevant climate impact information from wildfires. Mock-up of this dashboard is shown in Figure 5 bottom. Figure 6 depicts zoomed in mock-ups of the kinds of comparison graphs the *historical* tab will show.

[1] https://www.tableau.com/
[2] https://plotly.com/dash/
[3] https://github.com/tableau/TabPy



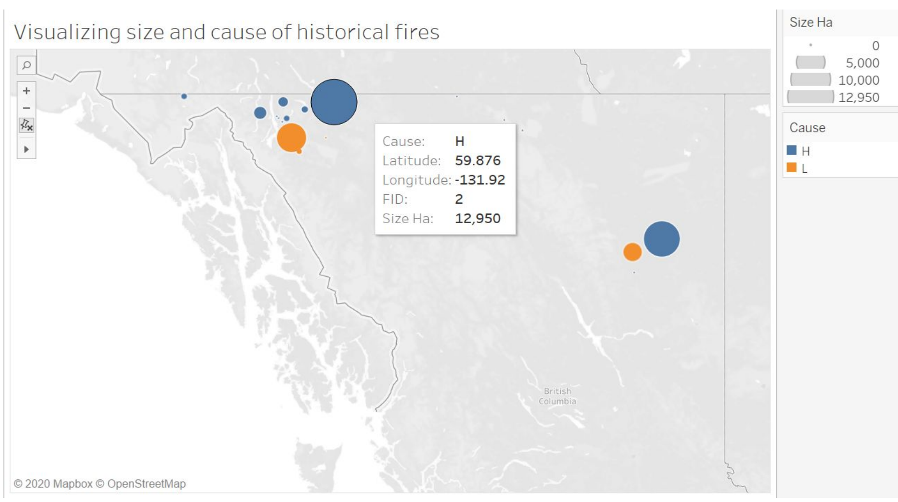


Figure 6. *Zoomed-in mock-ups of the comparison graphs shown in the historical tab.*

5.2 Results (Usage Scenarios)

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

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

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

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

6. MILESTONES

The milestones were divided in a way that all team members have similar workloads. A breakdown of each individual contribution can be seen in Table 1, and the total sum of hours per milestone can be seen in Figure 7.

Milestone	Hours per person (estimate)	Deadline	Task breakdown	Team member
Pitch	3	Oct 1	"Firest" and "Visualizing Wildfire Data"	Everyone
Pre-proposal meeting	3	Oct 13	Brainstorming project topic, collecting data sources and preparing meeting agenda	Everyone
Proposal	3	Oct 22	Meeting time	Everyone
	2.5		Brainstorm solution, define data sources	Everyone
	3		Report writeup	Everyone
Implementation	10	Ongoing	Learn selected tool (Tableau)	HE, PV
	7	Oct 30	Data cleaning	[Everyone]
	10	Nov 6	First draft of current tab implementation	HE, PV
	10	Nov 13	First draft of historical tab	RG, RC
	10	Nov 14	Merge views	[Everyone]
Update report	2	Nov 16	Update report	Everyone
Peer project review	2	Nov 18	Prepare demo/presentation	Everyone
Refined implementation	20	Dec 7	Polish implementation, prepare demo	Everyone
Final presentation	2	Dec 9	Prepare and rehearse presentation	Everyone
Final paper	6	Dec 13	Finalize report	Everyone

Table 1. *Proposed milestones and task breakdown.*

Amount of hours spent in each milestone

	Day of Start date								
Task name	September 27, 2020	October 1, 2020	October 22, 2020	October 30, 2020	November 13, 2020	November 14, 2020	November 19, 2020	December 1, 2020	Grand Total
Pitch	13 h								13 h
Pre-proposal meeting		12 h							12 h
Proposal		34 h							34 h
Implementation			48 h	40 h	40 h				128 h
Update report					8 h				8 h
Peer project review						8 h			8 h
Refined implementation							80 h		80 h
Final presentation								8 h	8 h
Final paper								24 h	24 h
Grand Total									315 h

Figure 7. *Estimated time to complete each milestone. Hours are aggregated across the whole team, estimated 80h per person*

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APPENDIX

D.1 Summary statistics derived from National Fire Database (NFDB) Agency Point data (NFDB_point_202008201) [17]

- Dataset Type: Table

Canada - Wildland Fire Summary Stats					
	NFDB_point_20200820			**NFDB_point_20200820_large_fires**	
Year	Fires	TOTAL_HA	MAX_SIZE_HA	FIRES>200ha	TOTAL_HA(>200ha)
2019	4,062	1,786,214	350,135	192	1,765,436
2018	7,111	2,328,851	156,775	428	229,030
:					
1960	2,856	597,841	41,625	256	584,942
1959	1,632	287,626	36,211	161	278,121

Table 2. *Structure of dataset 1: National Fire Database fire point data. The same attribute values are further available according to each Provincial Agency (AB, BC, MB, NB, NL, NS, NWT, ON, PEI, PC, QC, SK, YT). A total of 61 years of data available (1959 through 2019).*

- Data Types:
    - *Items* - Each item corresponds to one year's summarized data about wildfires
    - *Attributes, description and attribute types*: see Table 3
- Dataset Availability: Static

S.No.	**Attribute Name**	**Description**	**Attribute Type**
1.	YEAR	Year of fire	Ordered
2.	FIRES	Number of fires	Ordered (Quantitative)
3.	TOTAL_HA	Area burned due to fires	Ordered (Quantitative)
4.	MAX_SIZE_HA	Maximum size of fire in hectares	Ordered (Quantitative)
5.	FIRES>200ha	Number of large fires	Ordered (Quantitative)
6.	TOTAL_HA(>200ha)	Area burned due to large fires	Ordered (Quantitative)

Table 3. *Attributes and their descriptions (Dataset D.1)*.

D.2 NFDB Point Data (NFDB_point_202008201) [17]

- Dataset Type: Table

FID	SRC_AGENCY	FIRE_ID	FIRENAME	LATITUDE	LONGITUDE	YEAR	MONTH	DAY	REP_DATE	ATTK_DATE	OUT_DATE	DECADE	SIZE_HA	CAUSE	PROTZONE	FIRE_TYPE
0	BC	1953-G00041		59.963	-128.172	1953	5	26	1953-05-26 0:00			1950-1959	8	H		Fire
1	BC	1950-R00028		59.318	-132.172	1950	6	22	1950-06-22 0:00			1950-1959	8	L		Fire

MORE_INFO	CFS_REF_ID	CFS_NOTE1	CFS_NOTE2	ACQ_DATE	ECODISTRIC	ECOREGION	ECOZONE	CFS_ECOZ	SRC_AGY2
	BC-1953-1953-G00041			2020-05-05 0:00	925	181	12	12	BC
	BC-1950-1950-R00028			2020-05-05 0:00	905	177	12	12	BC

Figure 8. *Snapshots of the NFDB Point Data. The data goes from FID 0 to FID 413150. A smaller dataset is available that has only 18735 FID's and consists of only large fires (greater than equal to 200 hectares) out of the total 413151 rows available.*

- Data Types:
    - *Items* - Each item corresponds to one fire ID
    - *Attributes, description and attribute types*: see Table 4
- Dataset availability: Static

S.No.	Attribute Name	Description and Data Type	Attribute Type
1.	FID	Internal feature number. Sequential unique whole numbers that are automatically generated. Object identifier.	Categorical
2.	SRC_AGENCY	Agency (province, territory, parks) from which the fire data has been obtained. String.	Categorical
3.	FIRE_ID	Agency fire ID. String.	Categorical
4.	FIRENAME	Agency firename. String.	Categorical
5.	LATITUDE	Latitude. Double.	Ordered (Quantitative)
6.	LONGITUDE	Longitude. Double.	Ordered (Quantitative)
7.	YEAR	Year of fire as provided by individual agencies. Integer.	Ordered
8.	MONTH	Month of fire as provided by individual agencies. Integer.	Ordered
9.	DAY	Day of fire as provided by individual agencies. Integer.	Ordered
10.	REP_DATE	Date associated with fire as reported by individual agencies. Date.	Temporal
11.	ATTK_DATE	Date.	Temporal
12.	OUT_DATE	Date agency indicates fire is out or extinguished. Date.	Temporal
13.	DECADE	Decade. String. Hierarchical.	Categorical
14.	SIZE_HA	Fire size (hectares) as reported by the agency. Double..	Ordered (Quantitative)
15.	CAUSE	Cause of fire as reported by the agency.	Categorical

		String. Values: U(Unknown), L(Lightning caused fire), H(Human caused fire), H-PB(Prescribed burn human caused), Re(Reburn)	
16.	PROTZONE	Protection Zone as indicated by the source agency. String.	Categorical
17.	FIRE_TYPE	Fire type as indicated by source agency. String.	Categorical
18.	MORE_INFO	Additional attributes provided by the agency. String.	Categorical (descriptive)
19.	CFS_REF_ID	Fire reference ID. String.	Categorical
20.	CFS_NOTE1	Additional notes added by CFS when compiling the NFDB. String.	Categorical (descriptive)
21.	CFS_NOTE2		
22.	ACQ_DATE	Date that fire data was acquired from the agency. Date.	Temporal
23.	ECODISTRIC	Ecodistrict associated with fire point location. Data source The Ecological Framework of Canada: http://ecozones.ca/. Integer.	Categorical
24.	ECOREGION	Ecodistrict associated with fire point location. Integer.	Categorical
25.	ECOZONE	Ecodistrict associated with fire point location. Integer.	Categorical
26.	CFS_ECOZ	Ecodistrict associated with fire point location. Integer (one for each zone).	Categorical
27.	SRC_AGY2	Source agency (generally same as SRC_AGENCY). String.	Categorical

Table 4. *Attributes and their descriptions (Dataset D.2). Derived information from [18].*

D.3 British Columbia Data Catalog and Alberta Wildfire Database [19], [20]

- Dataset Type: Table

    - Data Types:
        - *Items* - Each item corresponds to one fire ID
        - *Attributes, description and attribute types*: similar to Table 3
- Dataset Type: Spatial
    - Data Types:
        - *Items* - Each item corresponds to one fire ID
        - *Positions*- defined by latitude and longitudes
- Dataset availability: Static