NORTHWEST
NAZARENE UNIVERSITY

FireMAP/FDL Update

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2022 US Frontier Development Lab – Dept of Energy

What if we could use ML-enhanced tools to prevent fires from starting or new fires from growing into large mega-fires?

NASA EPSCoR 2022-2023

Evaluation of Spatial Resolution and Spectral Band Selection on Wildland Fire Burn Severity Mapping

DISASTER RESPONSE

FDL 2022

WILDFIRE: MULTISPECTRAL ESTIMATION OF FUEL LOADS

FDL 2022 | Technical Presentation

Tuesday 20 September 2022

U.S. DEPARTMENT OF ENERGY

PARTNER

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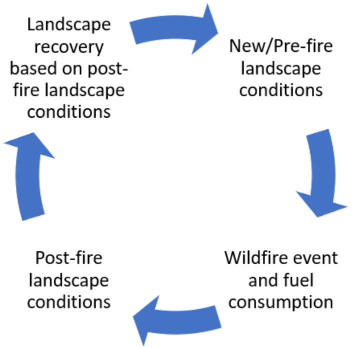
Researcher

1. Introduction

- **Wildfire is a very dynamic process!**

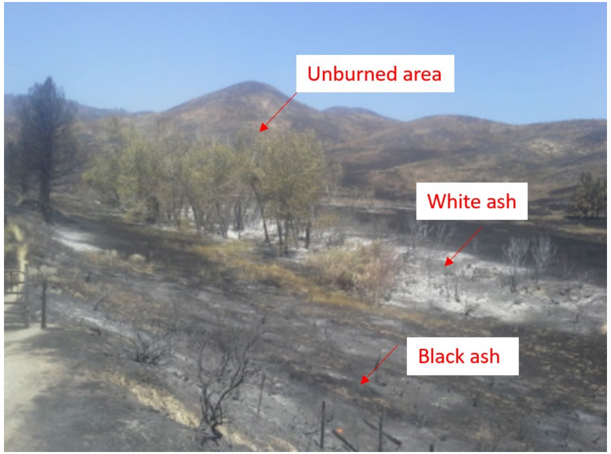


Landscape recovery based on post-fire landscape conditions

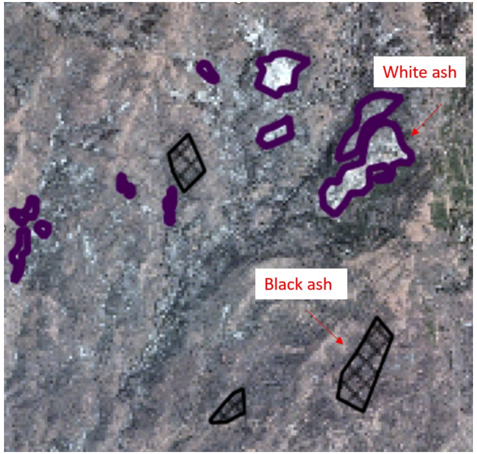
New/Pre-fire landscape conditions

Wildfire event and fuel consumption

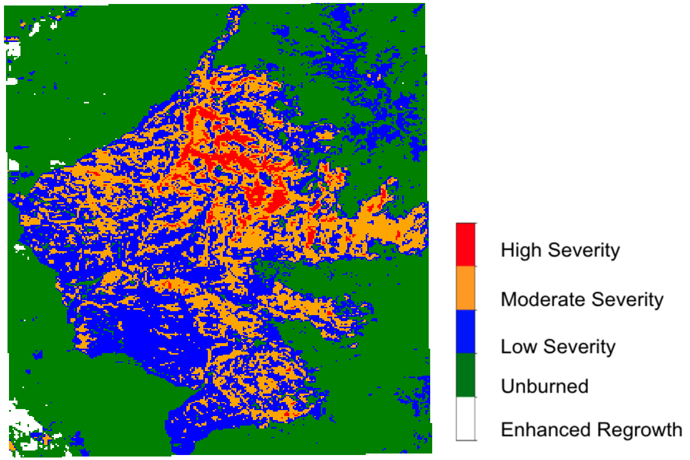
Post-fire landscape conditions



Example of ground view of fuel consumptions example (US)



Satellite view of fuel consumptions example (Mesa fire - US)



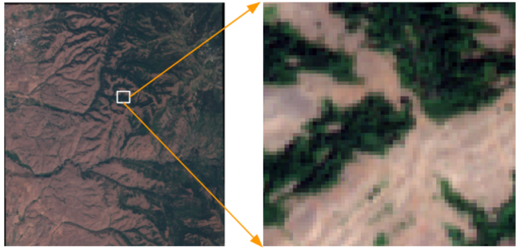
Example of a burn severity map

2. Methodology

- **Data acquisition**

Sentinel 2 (S2)

Resolutions:
- Spatial: 10 m
- Temporal: 5 days
- Spectral: 12 bands
RGB & NIR & SWIR were used in this study



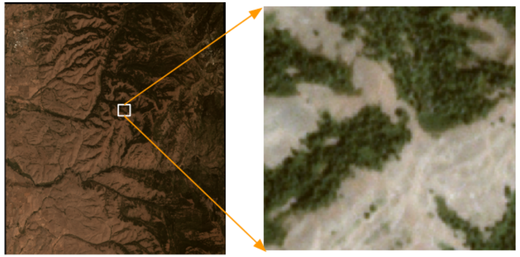
Pros:
- Better consistency over space and time
- Higher spectral resolution

Cons:
- Longer revisit time
- Lower spatial resolution

Challenge
- Clouds
- Longer revisit time

PlanetScope (PS)

Resolutions:
- Spatial: 3 m
- Temporal: 1 day
- Spectral: 4 bands
RGB & NIR were used in this study



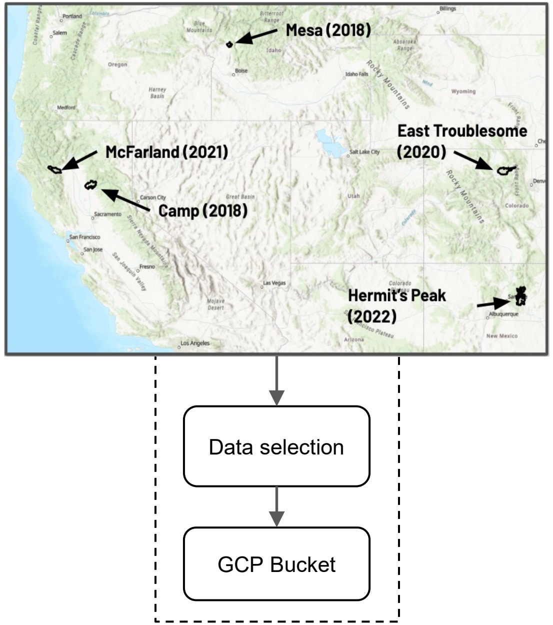
Pros:
- Higher temporal & spatial resolution

Cons:
- Lots of data wrangling
- Limited spectral resolution

Challenges
- **Mosaicking** full scene of study area
- **Gaps**
- **Clouds**
- Mix of sensor versions with **different number of bands**

2. Methodology

- **Data acquisition**
    - Nearly 10 million square kilometers of PlanetScope imagery was obtained (across 5 different study areas throughout the Western United States).
    - As long as the imagery covered enough of the study area (>50%) and did not have significant cloud cover, each PlanetScope and Sentinel-2 image was added to the dataset and could be considered either pre-fire, active fire, or post-fire imagery.
    - Only some locations and time frames were used as datasets for the tested methods.



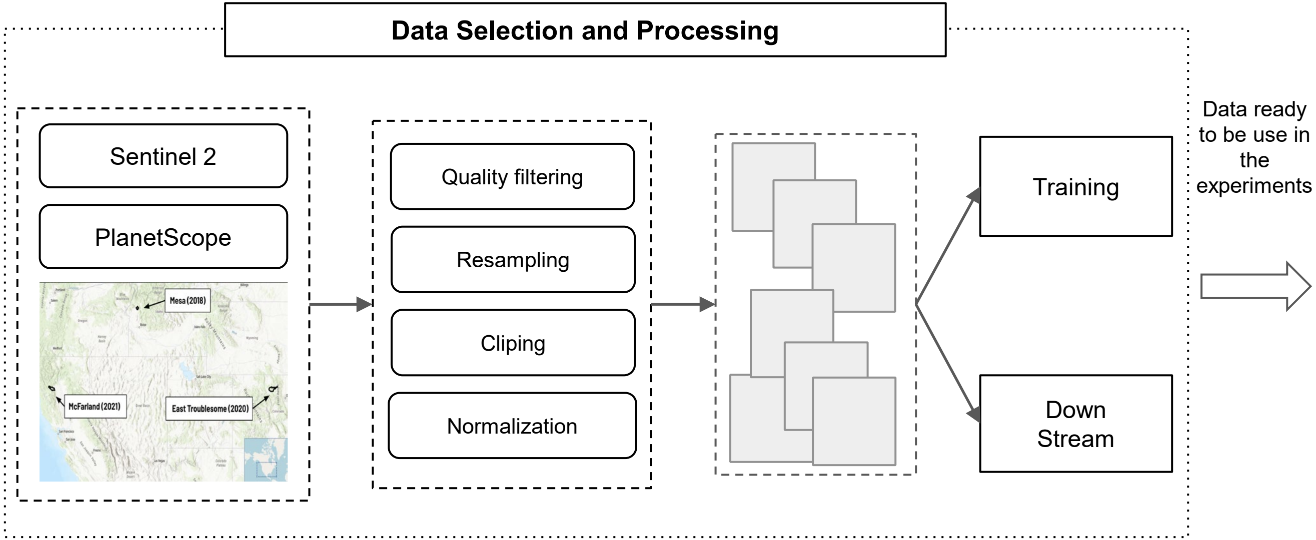
Data selection

GCP Bucket

Area of Interest	Fire Start Date	Containment Date	Time of Interest	Size (Acres)
Camp Fire	11/8/2018	11/25/2018	10/1/2018 to 12/1/2018	153,336
Mesa Fire	7/26/2018	9/25/2018	7/1/2018 to 10/1/2018	34,719
East Troublesome	10/14/2020	11/30/2020	10/1/2020 to 12/1/2020	193,812
McFarland Fire	7/29/2021	9/16/2021	7/1/2021 to 10/1/2021	122,653
Hermits Peak Fire	4/6/2022	8/23/2022	3/1/2022 to 8/31/2022	341,735

2. Methodology

- **Data pre-processing**
  - Once the data has been acquired it is placed in the GCP Wildfire Landing Bucket.
  - This data is not ready for any machine learning or geoprocessing and a few steps need to be followed first:



Data Selection and Processing

Sentinel 2

PlanetScope

Quality filtering

Resampling

Cliping

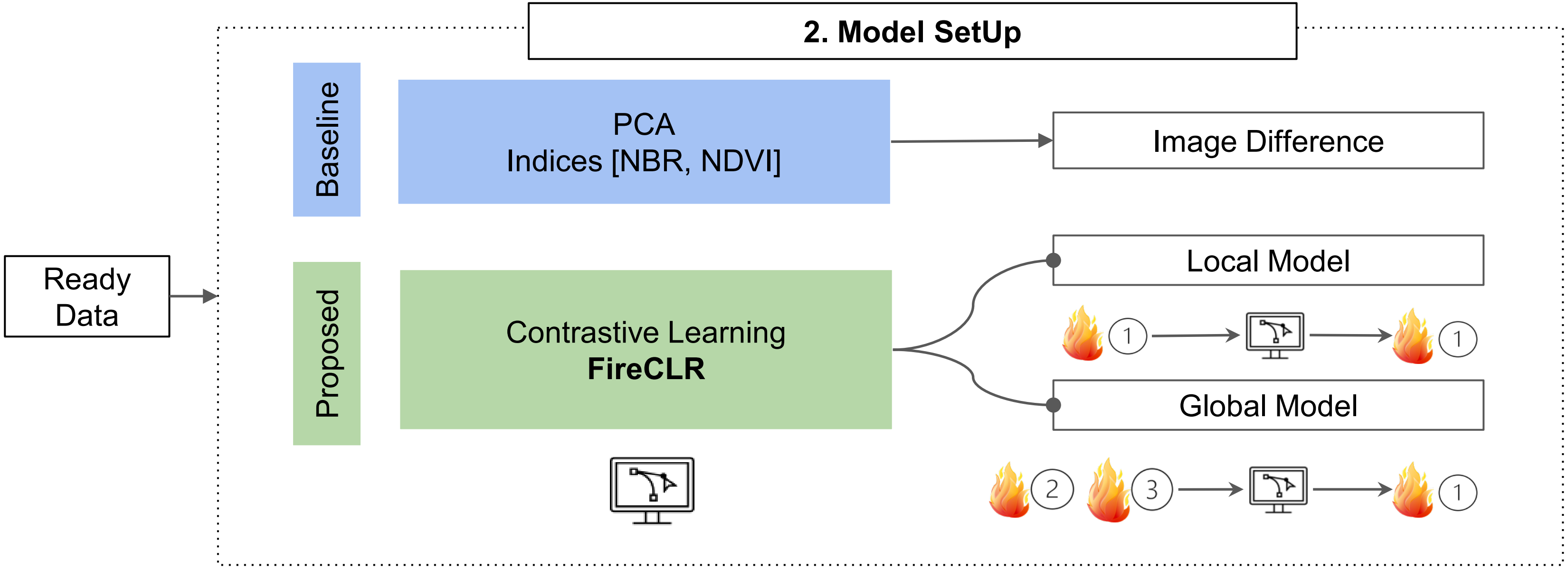
Normalization

Training

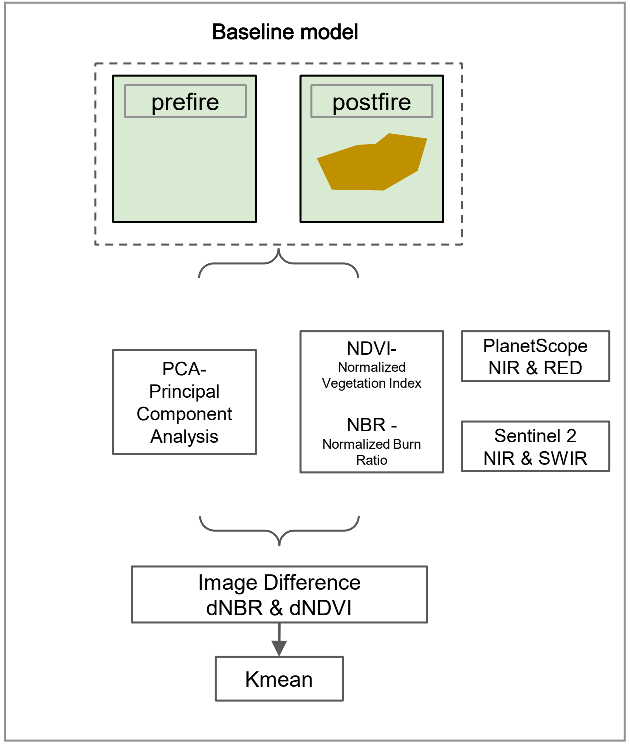
Down Stream

Data ready to be use in the experiments

2. Methodology - Model Setup



2. Methodology - Model Details



Baseline model

prefire

postfire

PCA-Principal Component Analysis

NDVI-
Normalized Vegetation Index

NBR -
Normalized Burn Ratio

PlanetScope
NIR & RED

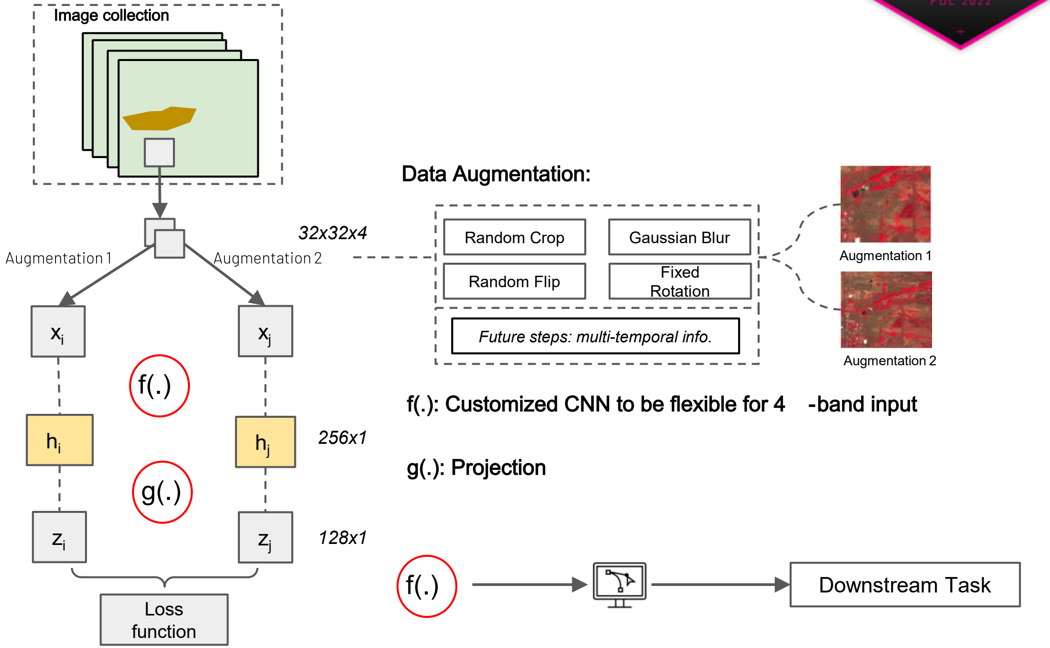
Sentinel 2
NIR & SWIR

Image Difference
dNBR & dNDVI

Kmean

✓ Pros: Easy to be built and explained

x Cons: Limited learning capability



Self-Supervised Learning - FireCLR (CNN-SimCLR)

Image collection

Augmentation 1

Augmentation 2

32x32x4

x_i x_j

f(.)

h_i h_j

256x1

g(.)

z_i z_j

128x1

Loss function

Data Augmentation:

Random Crop

Gaussian Blur

Random Flip

Fixed Rotation

Future steps: multi-temporal info.

Augmentation 1

Augmentation 2

f(.): Customized CNN to be flexible for 4 -band input

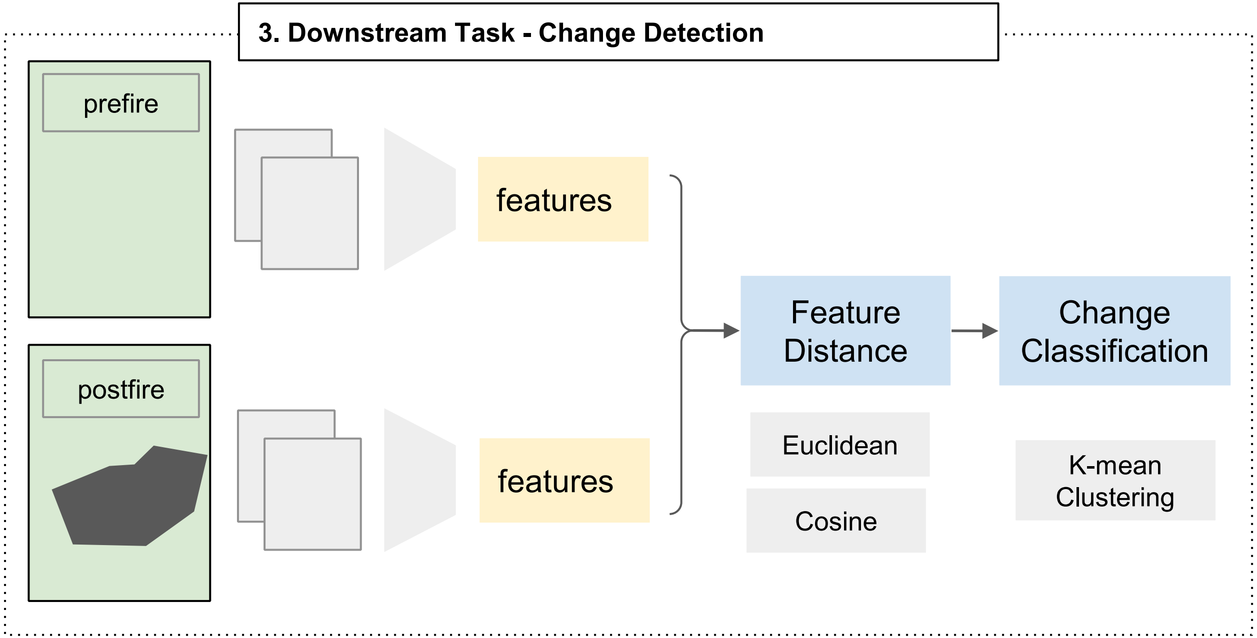
g(.): Projection

f(.) → → Downstream Task

✓ Pros: strong performance on extracting representation, reduce the chance of learning trivia information, SOTA model, best results (so far)

x Cons: computation and space very expensive, reduced spatial resolution of the output when doing the downstream task

2. Methodology - Downstream Task



3. Downstream Task - Change Detection

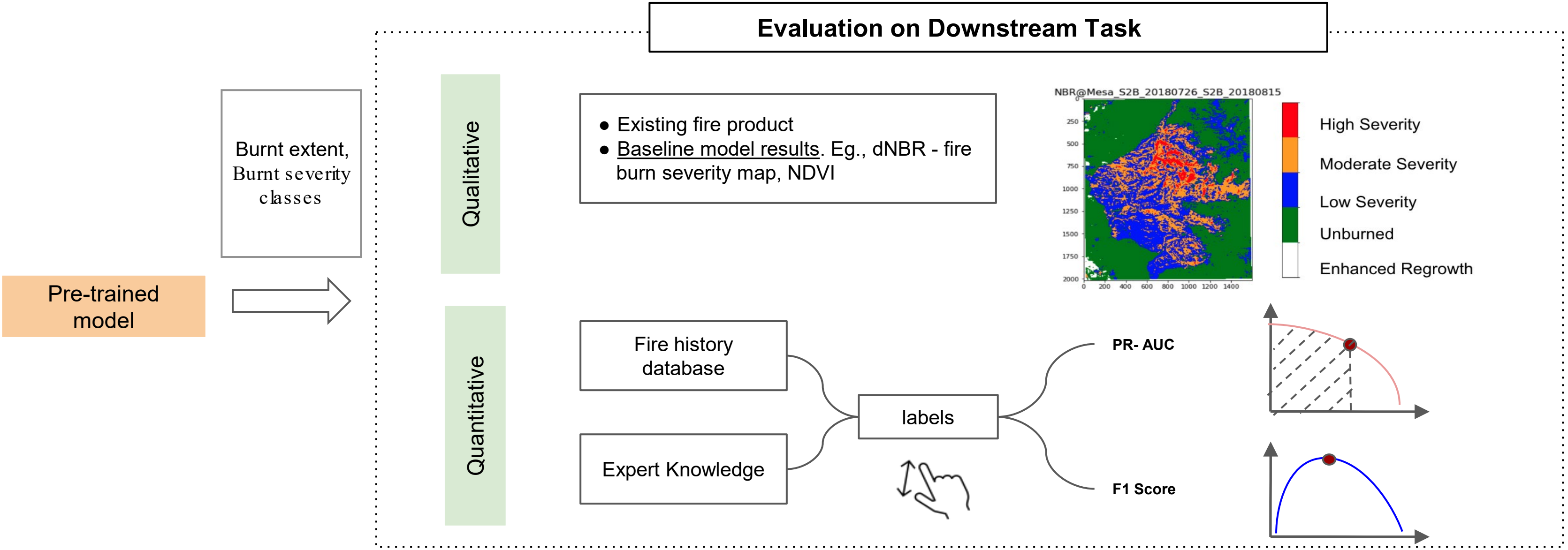
Feature Distance

- Euclidean
- Cosine

Change Classification

- K-mean Clustering

2. Methodology – Model Evaluation



Evaluation on Downstream Task

Pre-trained model

Burnt extent, Burnt severity classes

Qualitative

- Existing fire product
- Baseline model results. Eg., dNBR - fire burn severity map, NDVI

Quantitative

Fire history database

Expert Knowledge

labels

PR- AUC

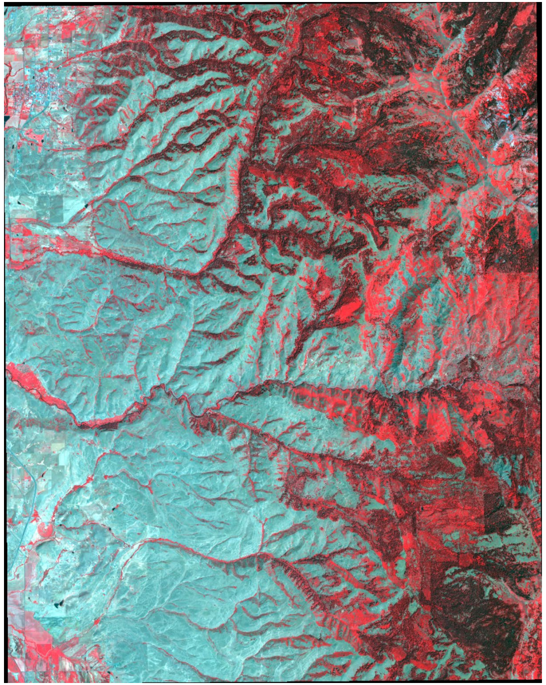
F1 Score

PR-AUC = precision recall area under the curve

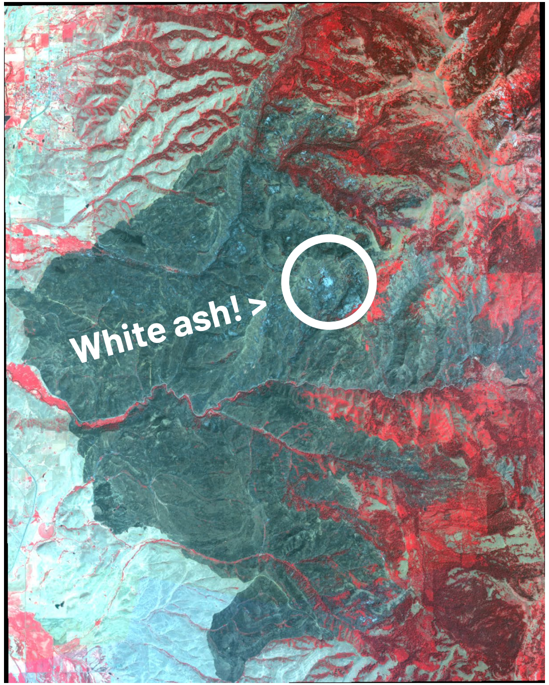
F1 Score = harmonic mean of precision and recall

Downstream task and validation: **Mesa Fire in Idaho, US (2018)**

BEFORE
PlanetScope - July 26



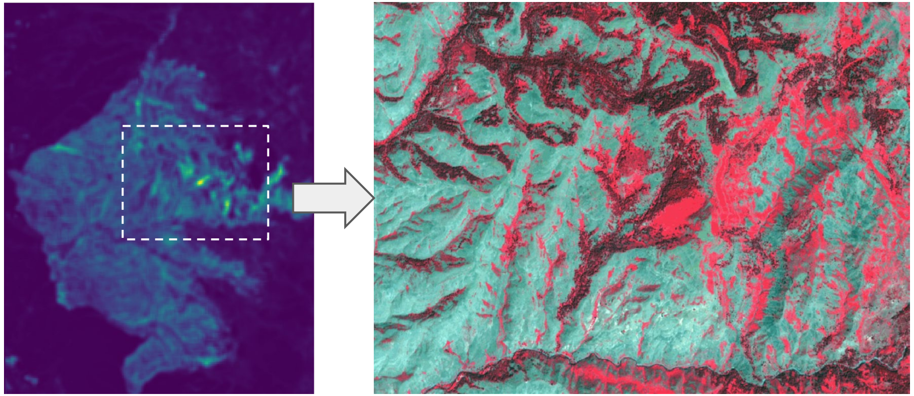
AFTER
PlanetScope - August 15



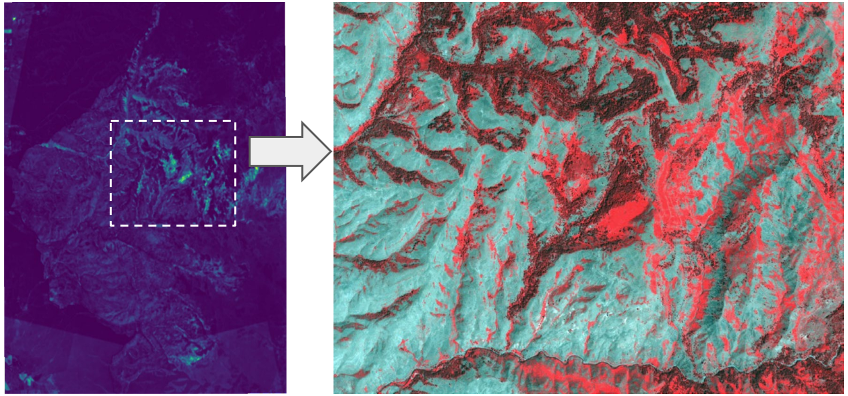
LABEL
of the Burned Area

3. Results

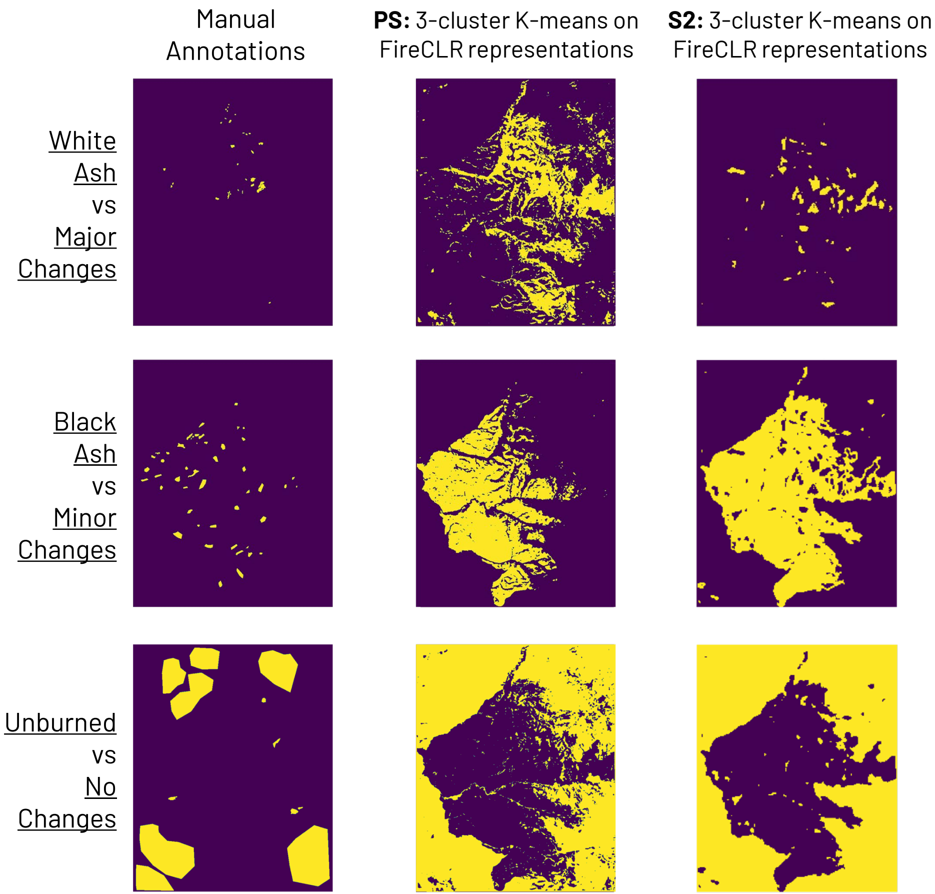
- **FireCLR Local model (S2)**
    - Trained and evaluated on same geographical location (different days - imagery at Mesa fire on July 26 & August 15)
- **PR-AUC = 0.99**
- **Δ(FireCLR - baseline) = 0.04**



- **FireCLR Global model (PS)**
    - Trained and evaluated on different geographical location (training using pre- and post-fire imagery at McFarland and East Troublesome fires / downstream using imagery at Mesa fire on July 26 & August 15)
- **PR-AUC = 0.80**
- **Δ(FireCLR - baseline) = 0.13**



FireCLR Downstream task and validation: Mesa Fire in Idaho, US (2018)



F1-score based on the Annotated Labels

	White Ash	Black Ash	Unburned
FireCLR + K-means (PS rgb+nir, res: 24m)	0.90	**0.86**	0.78
FireCLR + K-means (S2 rgb+nir, res: 80m)	0.51	0.82	**0.79**
PCA + K-means (PS rgb+nir, res: 3m)	0.90	**0.86**	0.76
PCA + K-means (S2 rgb+nir, res: 10m)	0.59	**0.86**	0.60
dNBR + K-means (S2 nir+swir, res: 10m)	**0.93**	0.78	0.76

6. Conclusions

- Key take away points
  - We developed **an change detection method, assessing the burned severity from a multitemporal perspective**. Our method is **fully unsupervised**.
  - We implemented **baseline methods** (dNBR/dNDVI) and a **contrastive learning ML model called FireCLR** designed to work in two modes, **local** (trained on the same geographical location as evaluated) and **global** (trained on different geographical location than evaluated).
  - For both datasets and both modes, **we report increased performance in comparison with the baseline models**. For the local model, **the PRAUC increased from 0.95 (baseline) to 0.99 (ML-model)**. For the global model, the PRAUC **increased from 0.67 to 0.80**.
    The models were also evaluated using F1-score based on the annotated labels for black and white ashes, against minor and major changes, respectively.

6. Conclusions

- Recommendations for **future works**
  - The proposed future work involves training the SimCLR model to be **invariant to natural changes with longer temporal series of data**.
  - Explore **different Planet products** (or other vendors) and trade-offs in spatial and spectral resolution relevant to wildfire mapping.
  - **Compare the results produced using contrastive learning against an autoencoder** to see if one algorithm is superior for mapping post fire effects.
  - Use the burn scar mapping from successive days to **produce a fire progression map showing fire growth at a finer temporal scale** than achieved with this experiment which compared pre and post fire imagery.
  - Investigate self-supervised contrastive learning for **identifying tree mortality**, resulting in a reduction in canopy cover.

IDAHO PRESS

Thursday, September 15, 2022

70°

Four Corners Fire nearly 100% contained

By KTVB STAFF Sep 13, 2022

The Four Corners Fire near Cascade had burned nearly 14,000 acres as of Tuesday.
KTVB

Originally published Sept. 13 on KTVB.COM.

Some areas on the Four Corners Fire west of Cascade continue to burn, but homeowners are being allowed to return to previously evacuated areas, and crews may have the fire completely contained within the next two weeks.

As of Tuesday, the fire had burned 13,717 acres and was 96% contained. No structures have been lost, according to officials with the Payette National Forest. Evacuation orders for the Campbell Creek and French Creek areas have been downgraded from "GO" (immediate evacuation) to "SET" (pre-evacuation). Homeowners in those areas are allowed to return, but should be prepared to evacuate again if necessary. At this time, only homeowners are allowed to return to the area.

BBC NEWS

Climate change: Europe's warm summer shatters records

By Matt McGrath
Environment correspondent

7 days ago · Comments

GETTY IMAGES

Fires were common in many places including here in Portugal

FDL

AD ASTRA
PER ALGORITHMOS

FOR ALL HUMANKIND

NASA
PARTNER

U.S. DEPARTMENT OF ENERGY
PARTNER

AITO

Google Cloud

NVIDIA

USGS
science for a changing world

LUXEMBOURG SPACE AGENCY

PASTEUR
Si

planet.

intel.

SETI
INSTITUTE

TRILLIUM USA

2023 NNU FireMAP efforts

Visiting Fellowship with The Australian National University Bushfire Research Centre of Excellence (Spring 2023 Sabbatical)

NASA funded Spatial/Spectral analysis

Reconcile 2022 US FDL Wildfire Challenge, Local vs Global methods

Support DOE funded 2023 US FDL Wildfire Challenge

Questions?