Alaska EPSCoR

All-Hands Meeting
Boreal Fire Component

February 8, 2023

Clear Fire 2022

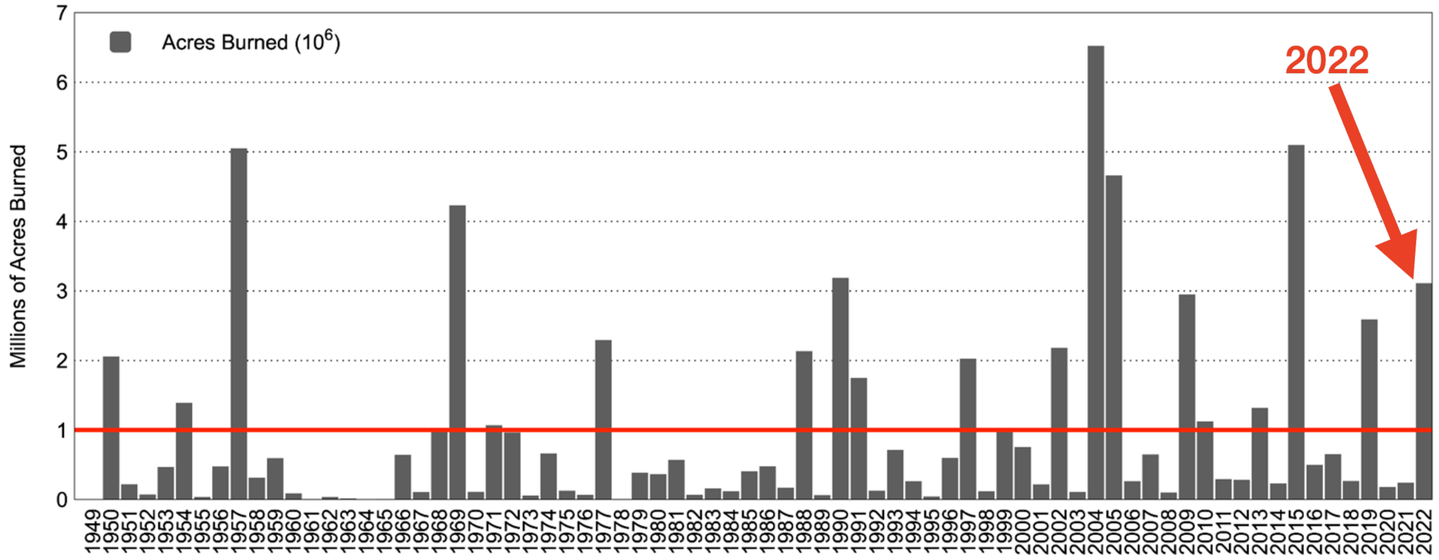
top: Eric Kiehn, Task Force Leader with Northwest Team 10

bottom: Cumulus formations from Parks Highway July 7, 2022

NSF

Alaska EPSCoR

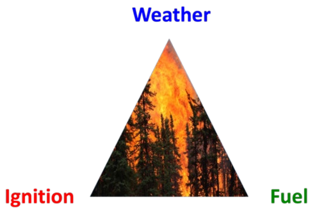
Larger fire seasons are becoming more common in Alaska



Duff plug from black spruce stand.

2022 had several unique attributes

- **Earliest start to the fire season - Kwethluk fire began on April 16th on the tundra**
- **In 2022 3.3 million acres burned with record number of acres in SW Alaska**
- **Also unusual was the abrupt start and end in 2022 in Interior Alaska**



Boreal Fires Research Goals

Goal BF1

Produce seasonal fire outlooks by merging data on lightning probability and available fuels with seasonal climate forecasts.

Goal BF2

Enhance active fire characterization, spread prediction, and severity assessment in the boreal through improved remote sensing, short-term weather data, and field measurements.

Goal BF3

Develop science-based options for improving wildfire management policy to maintain ecosystem service flows and foster community resilience.

Goal BF4

Hire and train researchers and share results with academic audiences and stakeholders.

Interrelation of Research Goals 1-3

Preparedness

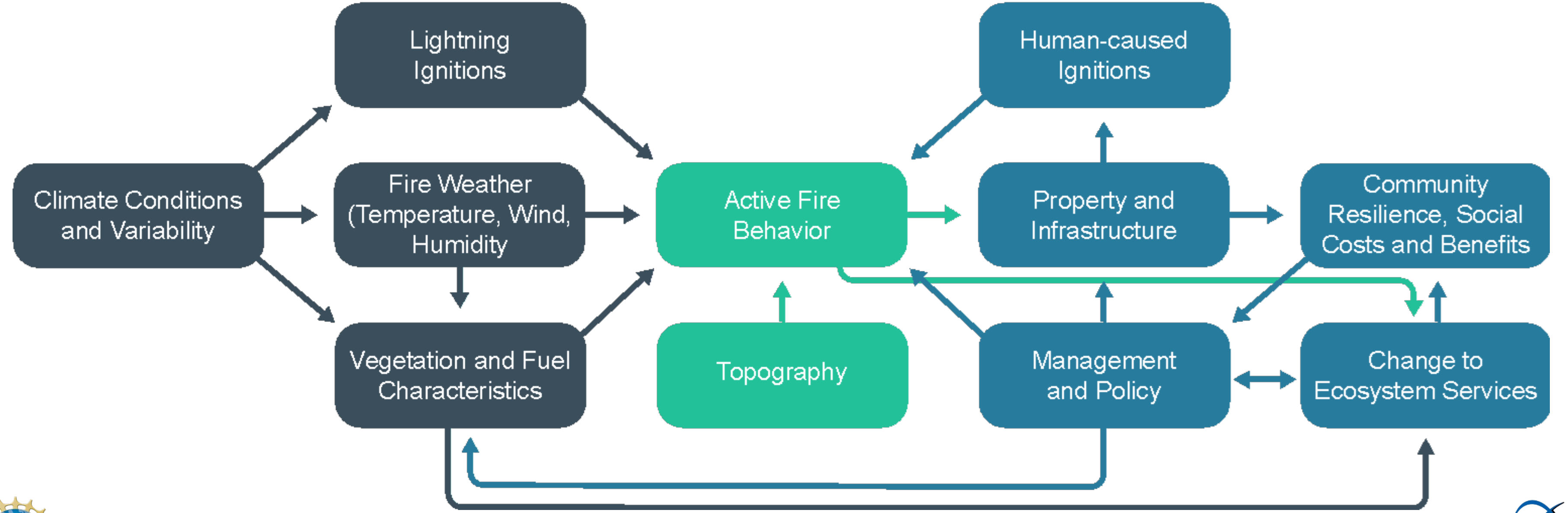
Q1: Fire Risk (≤ 1 year)

Response

Q2: Active Fire Behavior (hours to days)

Recovery

Q3: Human-Wildfire Interaction (fire ± 2 years)



Multidisciplinary Research Team

Climate Variability


Uma Bhatt
(co-lead)


Peter Bieniek

Ecology


Todd Brinkman
(co-lead)


Erik Schoen

Economics and Ecosystem Services


Matt Berman


Jen Schmidt


Kynan Hughson
(UAA Faculty Hire)

Fire Management


Mitch Burgard


Teresa Hollingsworth


Randi Jandt


Alison York

Remote Sensing and Fuel Mapping


Santosh Panda


Martin Stuefer


Chris Waigl
(postdoc)

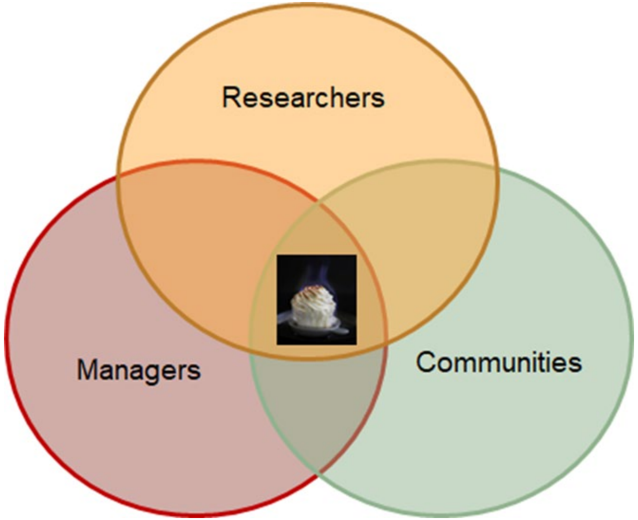

Simon Zwieback
(UAF Faculty Hire)

NSF
ALASKA FIRE SCIENCE CONSORTIUM
Tanana Chiefs Conference
Alaska EPSCoR

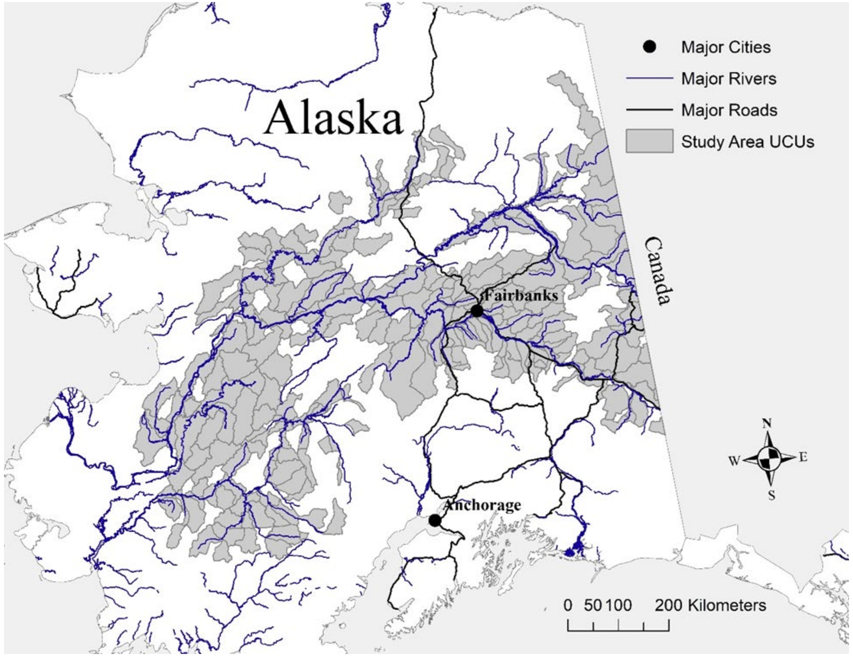
Ecosystem Services & Wildland-Urban Interface Group

Our aim was to co-produce knowledge on the effects of wildfire on:

- Availability of ecosystem services
- Wildland-urban interface



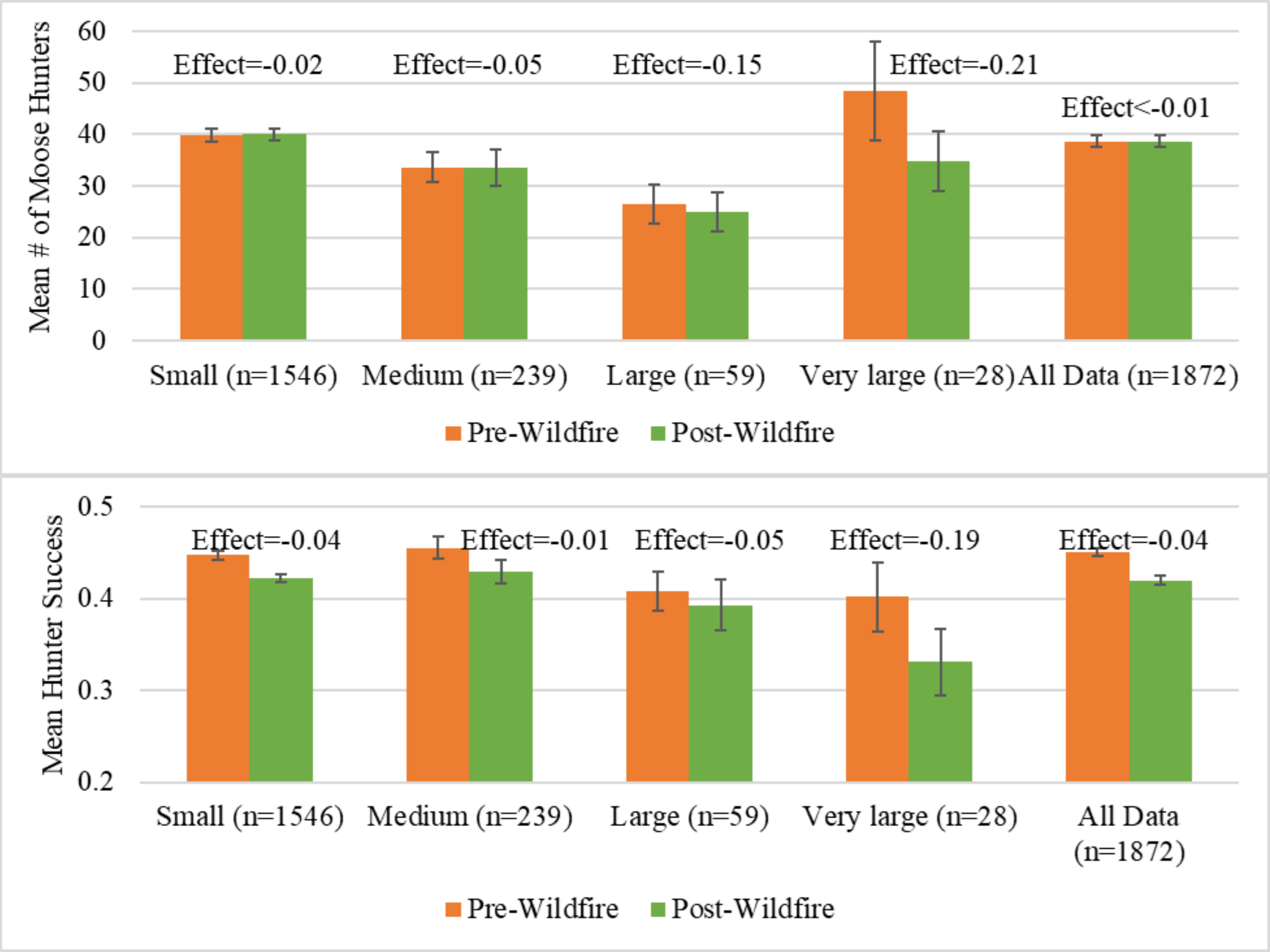
Immediate Effects of Wildfire on Moose Harvest



Model variables:

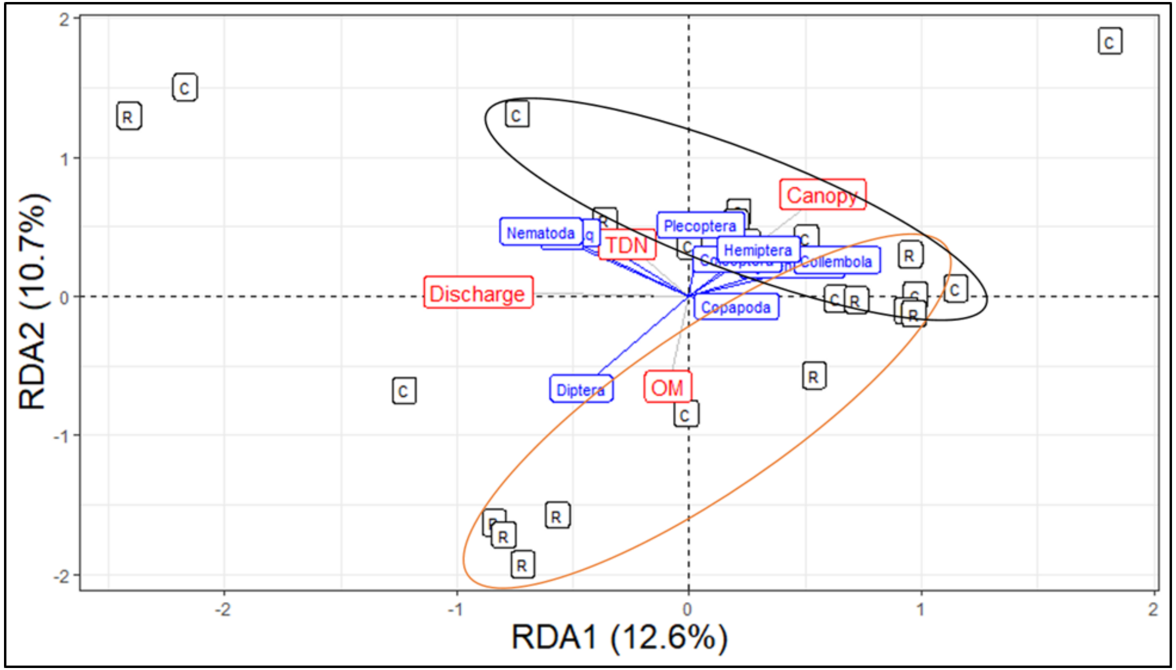
- Moose harvest data - 1983-2019
- Predictors - wildfire characteristics, habitat burned, hunter access

Wildfires have a very small effect on moose hunting



Statistical effect estimated in only the very largest (1.5%) wildfires

Post-wildfire response of headwater streams in the boreal forest



<u>Shovel Creek Fire</u>

23,000 acres burned in 2019

Sampled 3 headwaters of two streams monthly June-September 2020 (n=24)

-Shovel Creek
-McCloud Creek

Exploring effects of wildfire on juvenile Chinook salmon

- Chinook salmon declines have caused hardship in fishing communities throughout Alaska
- Understanding wildfire effects on salmon is a critical knowledge gap identified by Alaska Native communities

Question: How does wildfire affect juvenile Chinook feeding and growth?

Research opportunity: The 2019 Nugget Creek Fire bisected a major Chinook spawning and rearing area on the Chena River

Objectives: Compare water quality, invertebrate drift, and salmon body size between fire-influenced and reference sites one year later

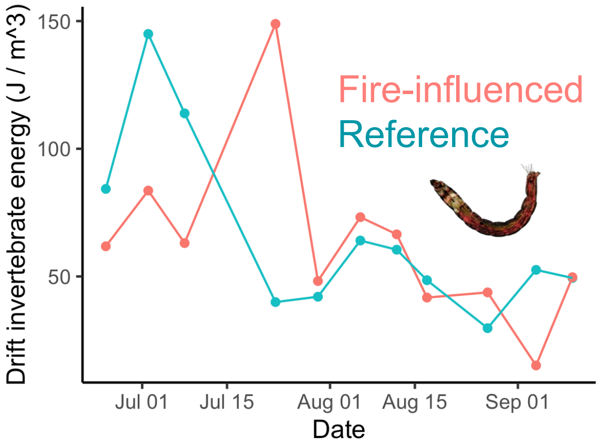
Tributaries

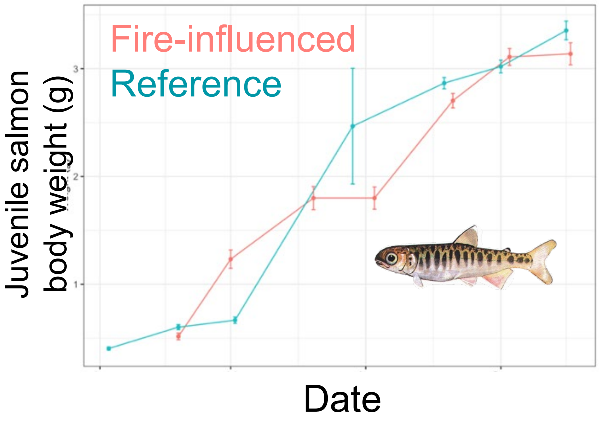
Mainstem

Wildfire changed water clarity, but not fish food or juvenile salmon growth

Fire-influenced mainstem reach

- Turbidity 74% greater (±25% SE; $p < 0.01$)
- Temperature only slightly warmer (0.3° ± 0.2°C; $p = 0.2$)





When beavers get burned, do fish get fried?

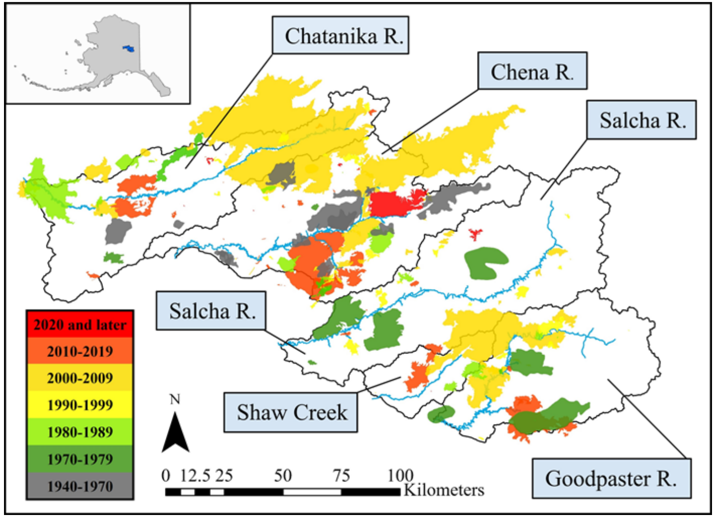
William Samuel, Jeff Falke, Ken Tape, Santosh Panda, Andrew Seitz

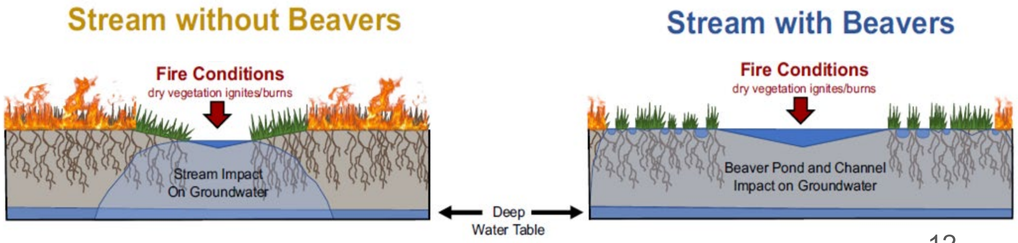
Background

- Beavers and wildfires interact
- Both beavers and wildfires have important effects on fish

Research Question

- How do beavers mediate the effects of wildfire on fish and aquatic habitat?
  - **We must first ask how fires affect beavers**





Adapted from Fairfax and Whittle 2020

When beavers get burned, do fish get fried?

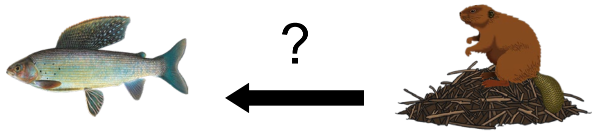
William Samuel, Jeff Falke, Ken Tape, Santosh Panda, Andrew Seitz

Methods

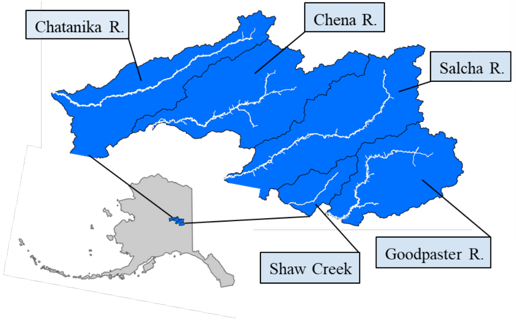
- Satellite imagery to enumerate beaver ponds (n=218)
- Model effects of wildfire characteristics on beaver pond characteristics

Preliminary Results

- Burned areas had more but smaller beaver ponds
- Exploring whether wildfire characteristics can predict beaver pond abundance and distribution

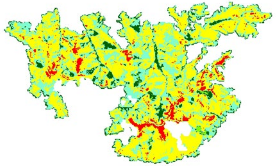


Study Area

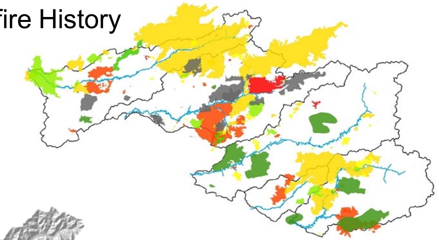


Beaver Ponds

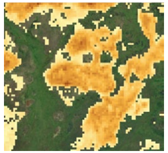
Burn Severity



Wildfire History



Digital Elevation Models (DEMs)

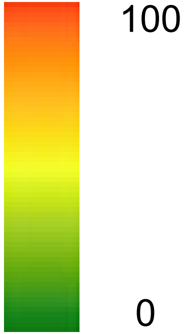


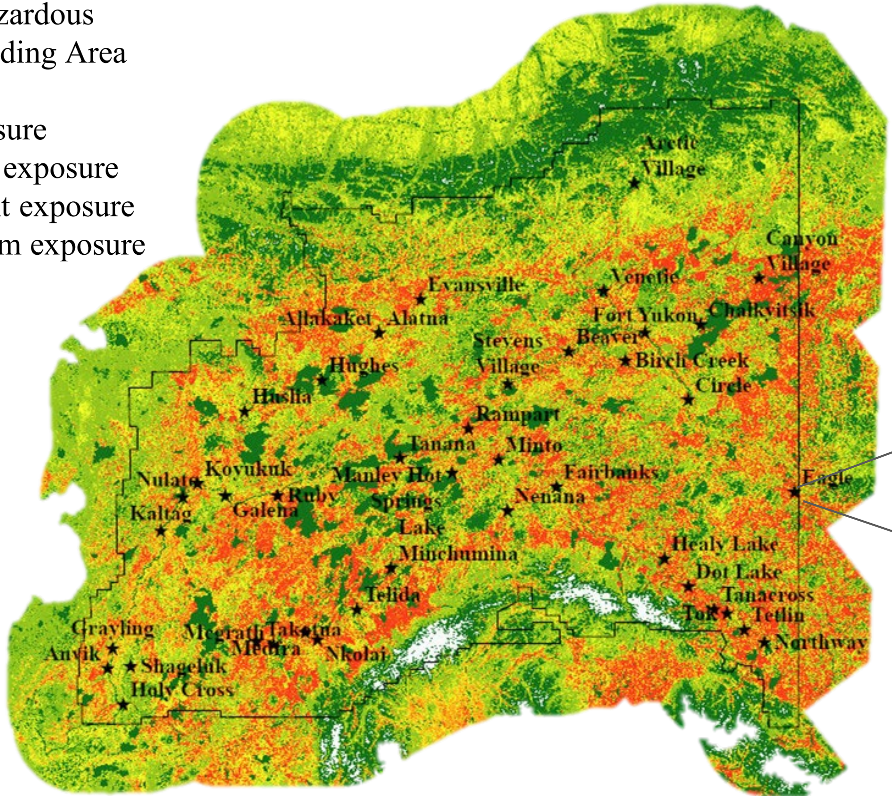
Vegetation Models

Estimating Wildfire Risk Around Rural Communities in Alaska

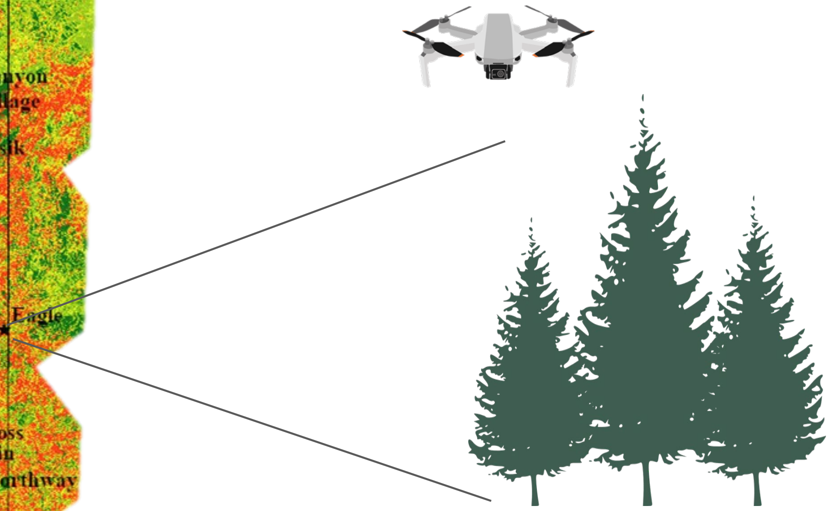
M.S. student Michelle Quillin

Exposure To Hazardous Fuels In Surrounding Area
0-20, very low
20-40, low exposure
40-60, moderate exposure
60-80, significant exposure
80-100, maximum exposure



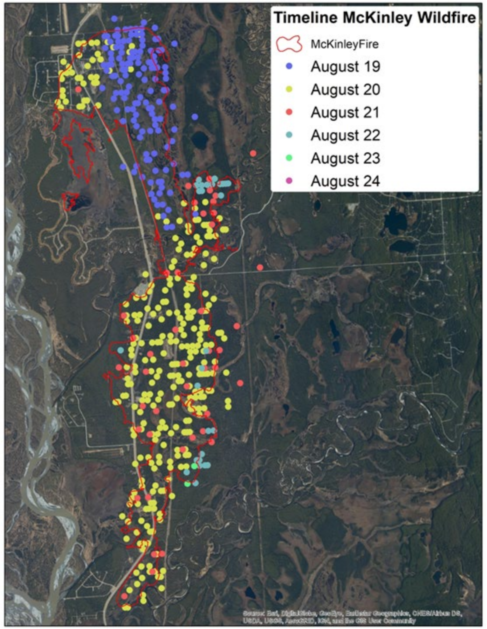


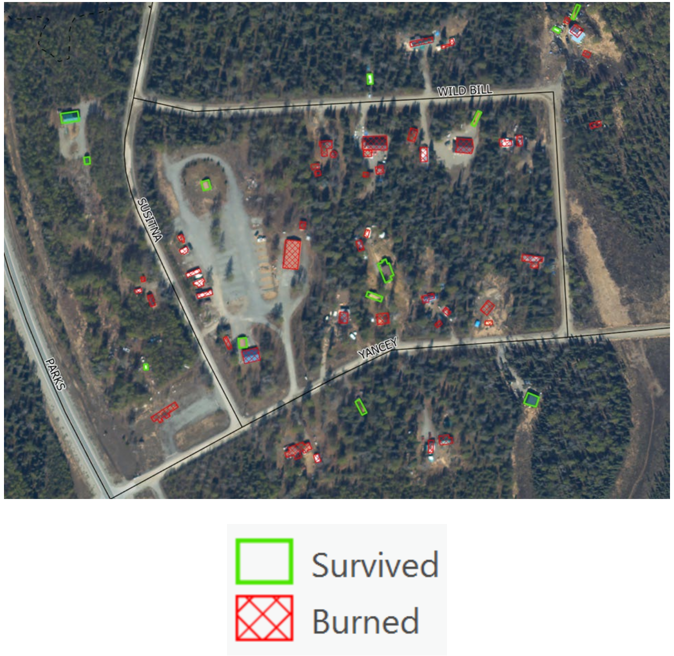
Increase capacity for forest research in rural communities using drones



Tanana Chiefs Conference

What socio-ecological factors are associated with buildings that burned during the McKinley wildfire?





Ecological

- Wildfire hazard on parcel
- Percent cover of trees around buildings at different scales (10, 30, 100, 500m)
- Burn severity from Sentinel-2

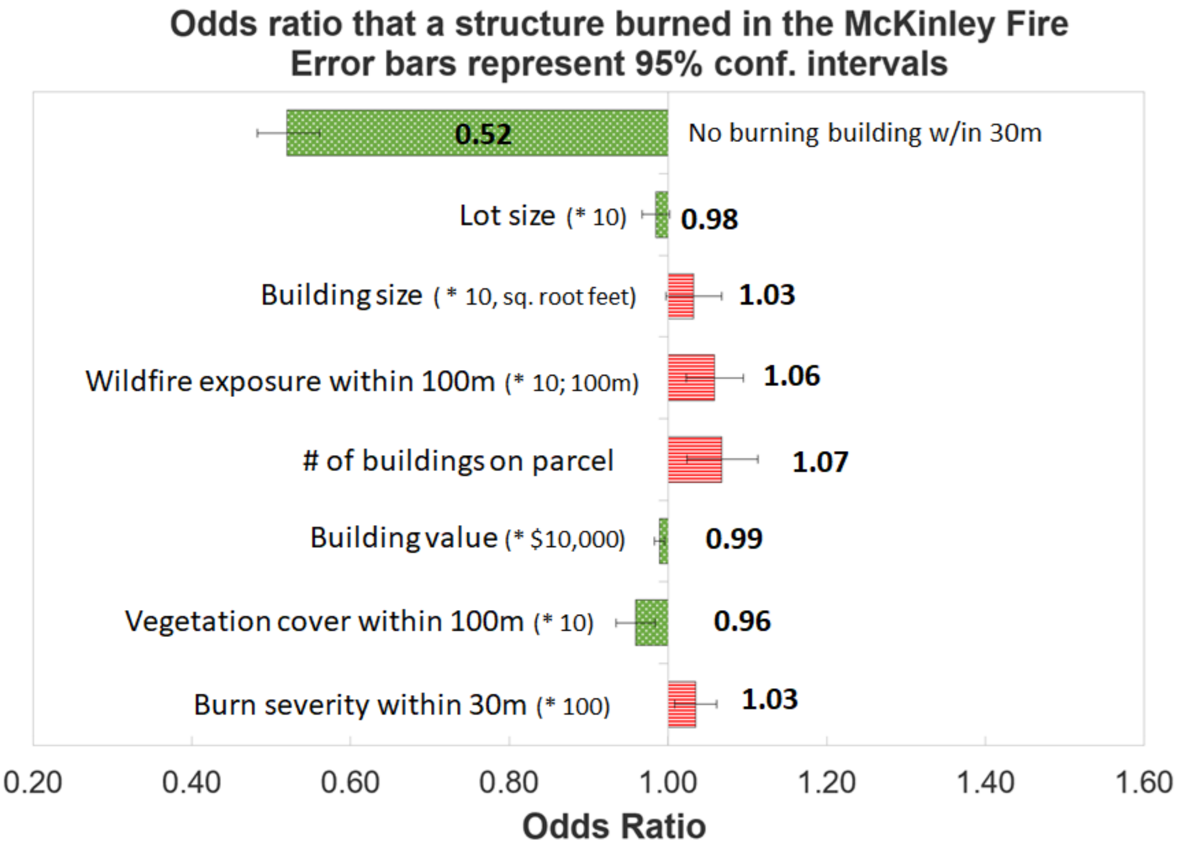
Social

- Near other buildings
- Lot size
- Value of home
- Building size

McKinley wildfire research: results

When there is no building burning within 30m: 48% lower odds of the structure burning

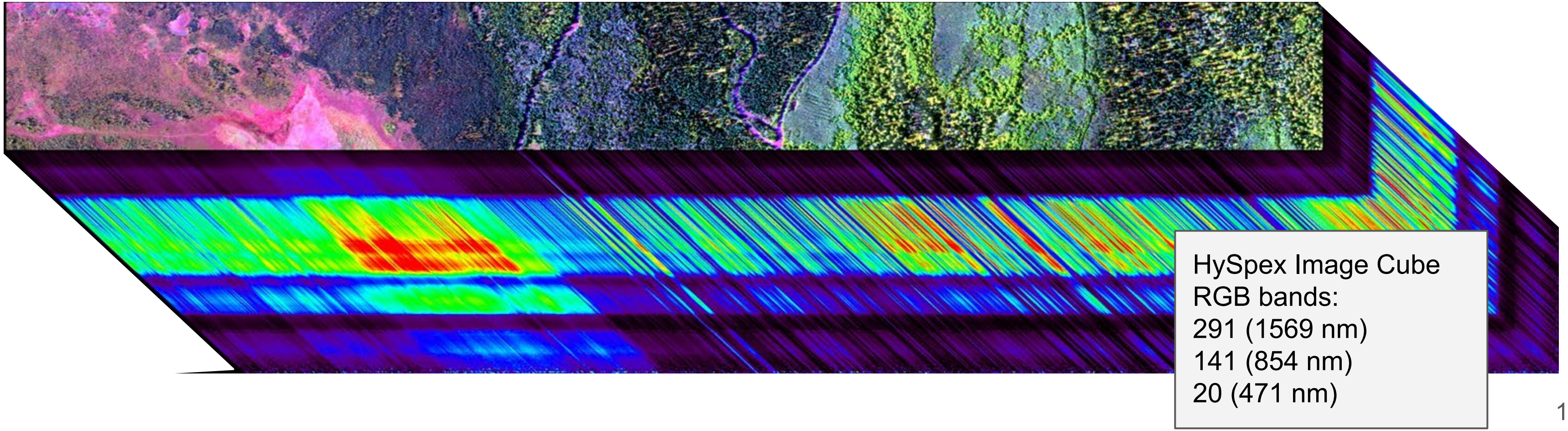
For every 100 increase in burn severity 3% increase odds of the building burning



Fuel mapping & remote sensing activities

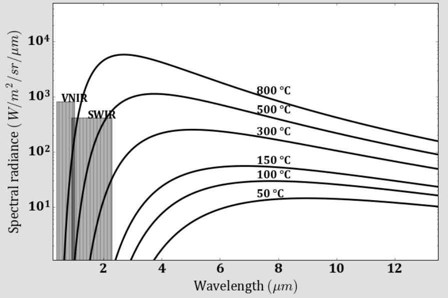
Wildfire fuels science results

a. **Anushree Badola:** new results from vegetation mapping with simulated hyperspectral data
b. **Santosh Panda:** Alaska-wide mapping tool
c. **Chris Waigl:** on tree to stand scale fuel mapping with HySpex
d. **Simon Zwieback** w/ Yuan Tian / Jessie Young-Robertson: fuel condition & insect damage

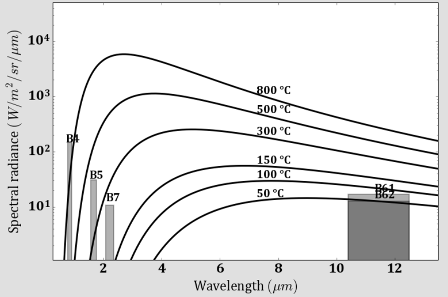


We use hyperspectral and multispectral remote sensing to characterize wildfire fuels, as well as active and post-fire signals

Hyperspectral sensor (eg. Hyperion, HySpex)



Multispectral sensor (eg. Landsat, Sentinel-2)



Watch our wonderful video "Introduction to Hyperspectral Imaging" on YouTube!
https://www.youtube.com/watch?v=0gs-Ohg8KIM

Vegetation Mapping in Boreal Region of Alaska

Objectives:

Develop novel algorithms for improved (finer resolution and better accuracy) vegetation/fuel mapping for boreal Alaska including conifer fraction

Output Products:

- Simulated hyperspectral data
- Improved vegetation map
- Needleleaf cover map

remote sensing   MDPI

Article

Hyperspectral Data Simulation (Sentinel-2 to AVIRIS-NG) for Improved Wildfire Fuel Mapping, Boreal Alaska

Anushree Badola [1,*], Santosh K. Panda [1,2], Dar A. Roberts [3], Christine F. Waigl [1], Uma S. Bhatt [1], Christopher W. Smith [1] and Randi R. Jandt [4]

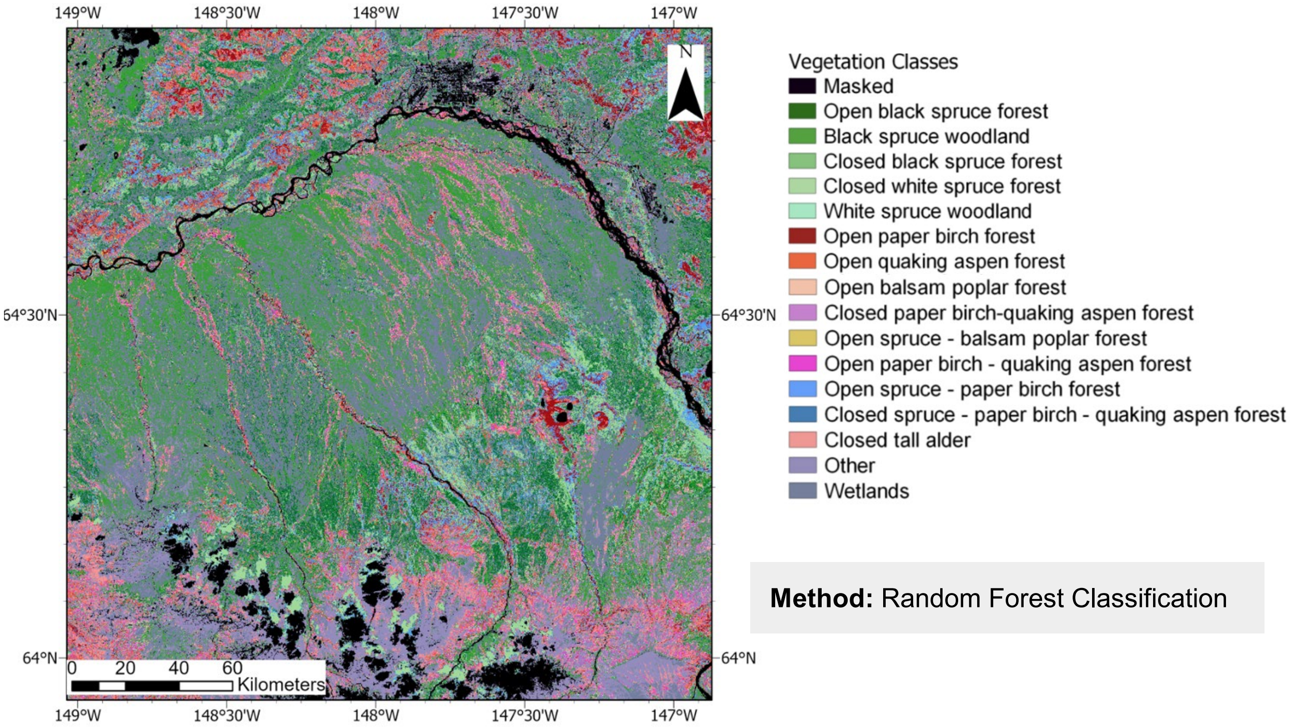
Badola et al. (2021), Editor's Choice

International Journal of Applied Earth Observation and Geoinformation
ELSEVIER
Volume 112, August 2022, 102891

A novel method to simulate AVIRIS-NG hyperspectral image from Sentinel-2 image for improved vegetation/wildfire fuel mapping, boreal Alaska

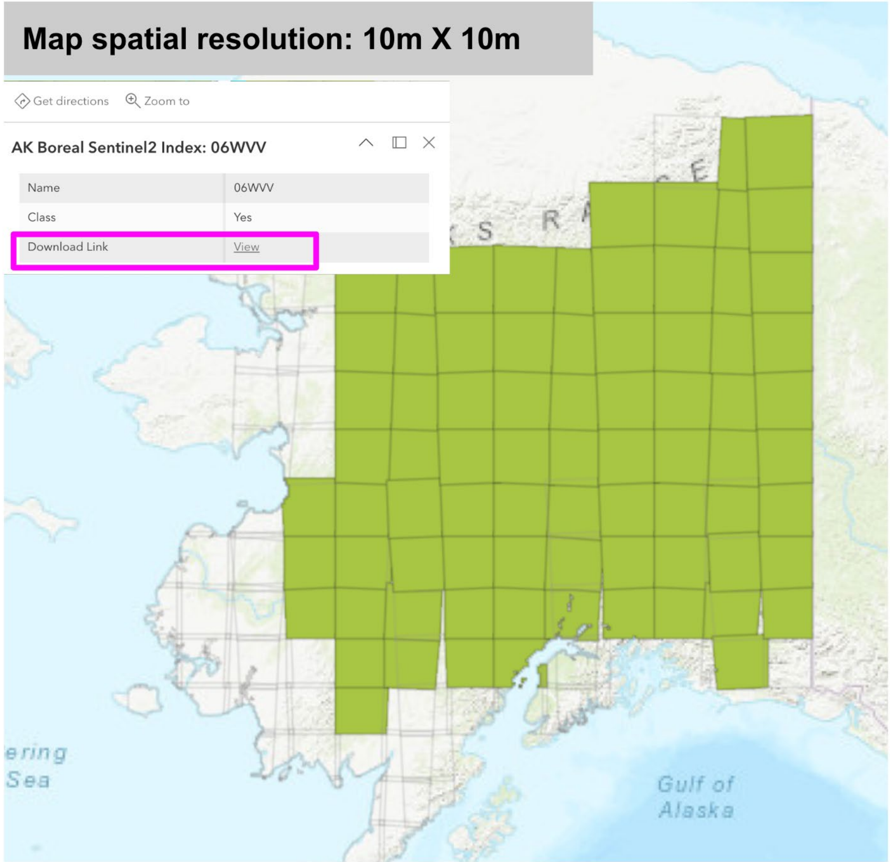
Anushree Badola [a], Santosh K. Panda [a b], Dar A. Roberts [c], Christine F. Waigl [d], Randi R. Jandt [e], Uma S. Bhatt [a]

Badola et al. (2022)

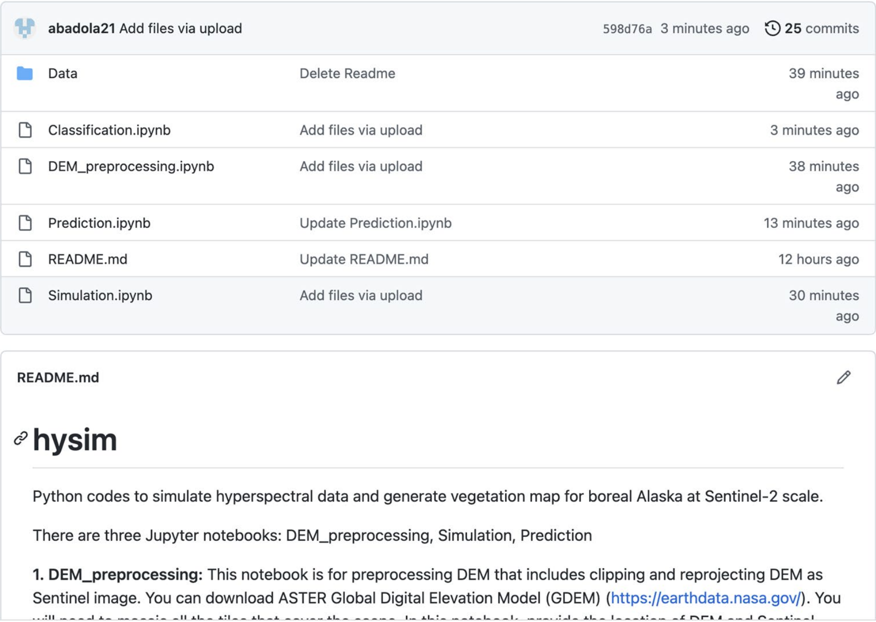


Method: Random Forest Classification

Download Vegetation Map (.tif layers)

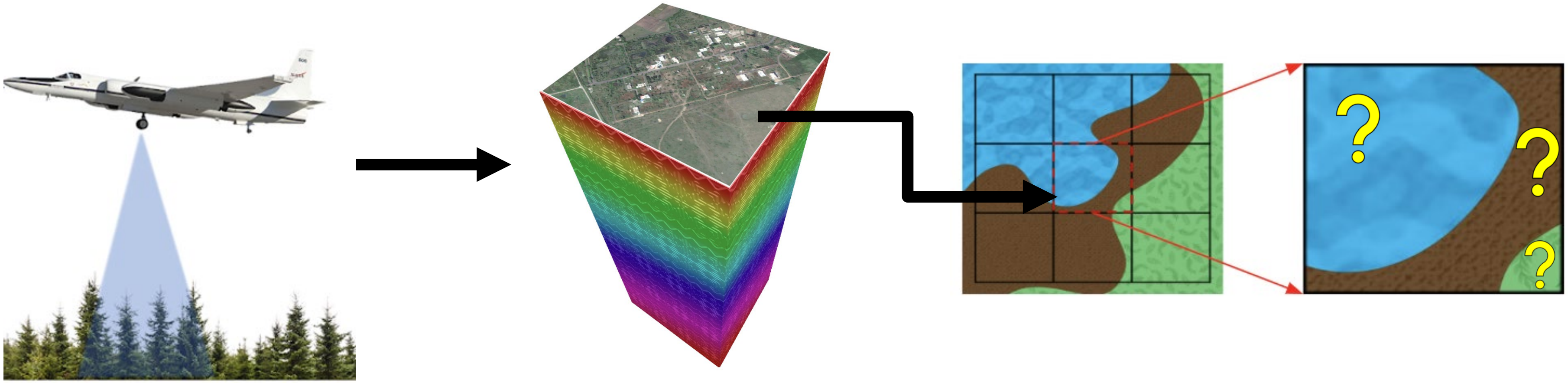


Codes Sharing



Github Link:
https://github.com/abadola21/hysim

Pixel Unmixing using MESMA



AVIRIS-NG (airborne data)

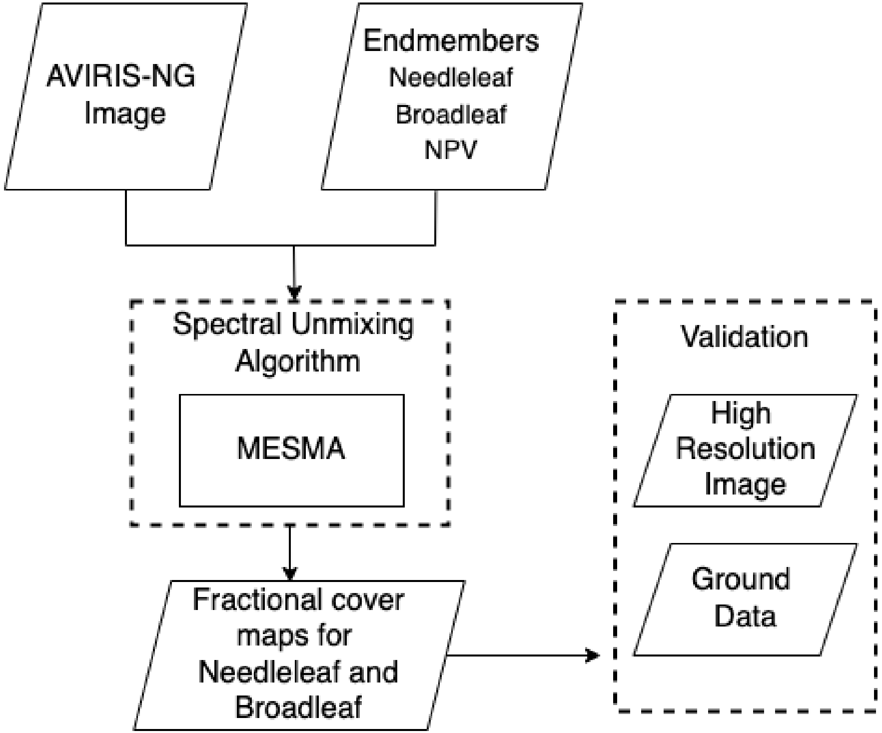
Hyperspectral image: 425 bands

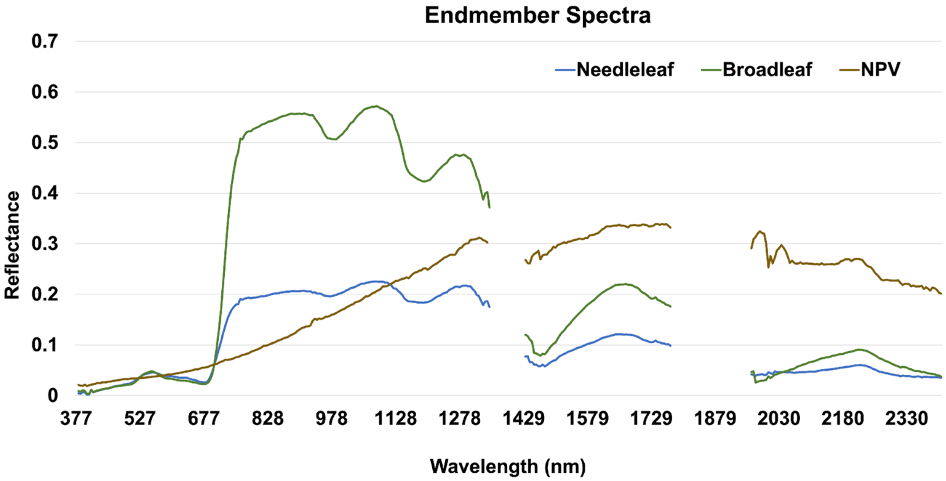
Image pixel: multiple classes

Research Questions:

1. Can pixel unmixing estimate the needleleaf fraction in a mixed boreal forest?
2. How do we validate pixel unmixing estimations?

Methodology





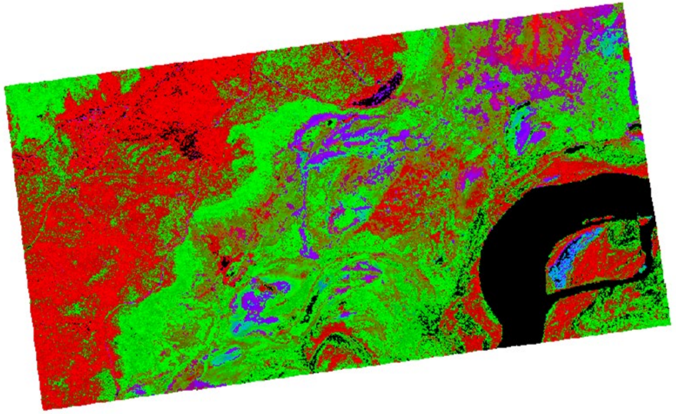
AVIRIS-NG: Airborne Visible InfraRed Imaging Spectrometer - Next Generation
MESMA: Multiple Endmember Spectral Mixture Analysis
NPV: Non-Photosynthetic Vegetation

Crabbé et al. (2020)

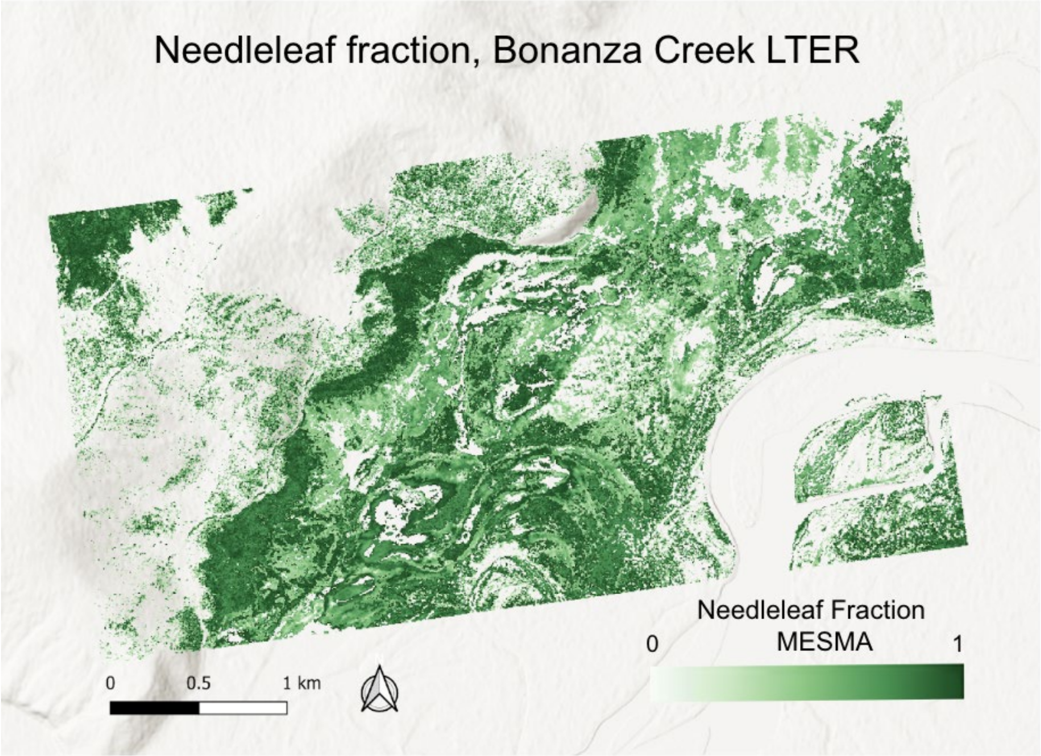
Manuscript (in prep)
Presented at AGU Fall Meeting 2022

Result

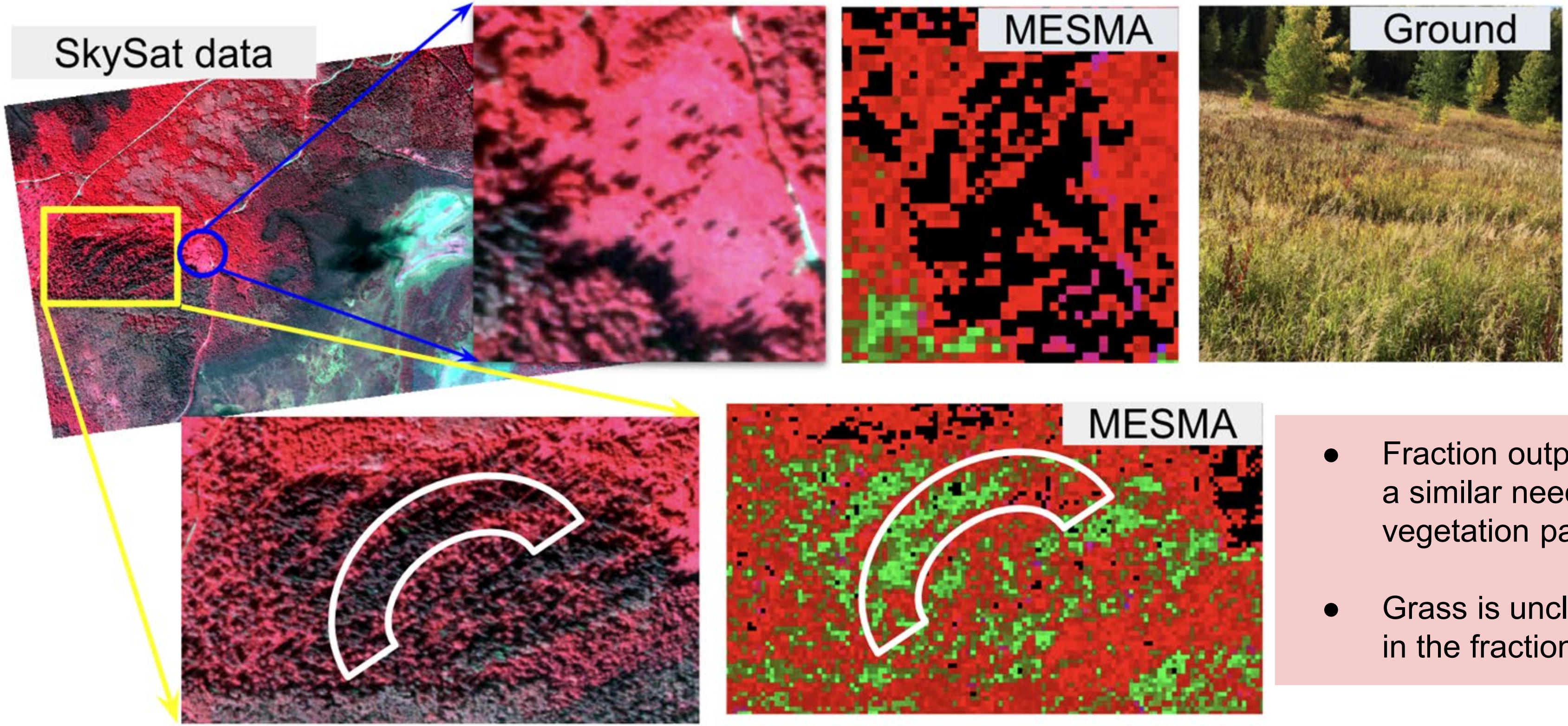
MESMA output



Channel	Class
Red	Broadleaf
Green	Needleleaf
Blue	NPV

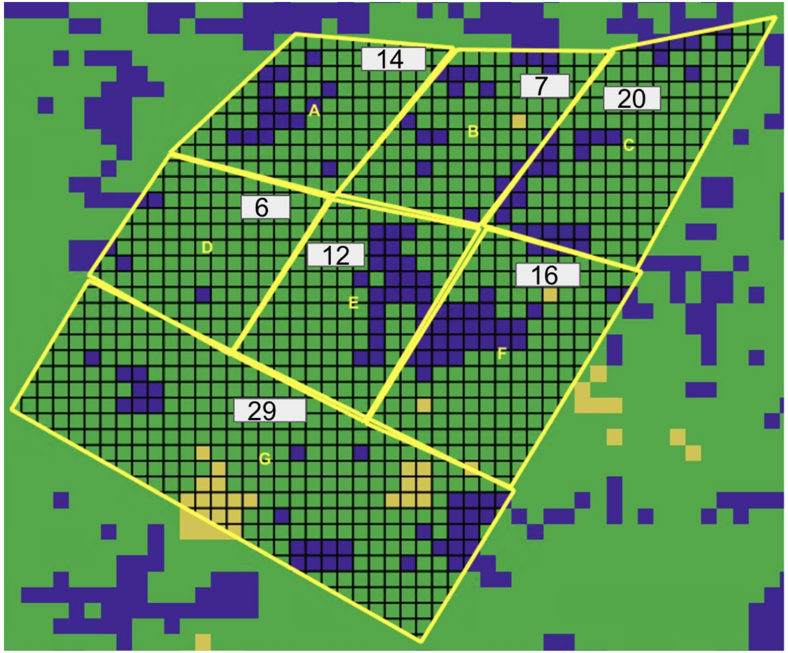


Visual Comparison with High Resolution Data

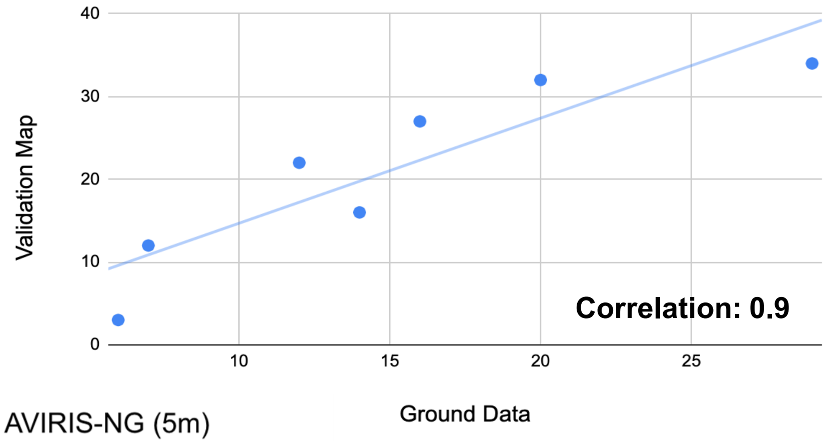


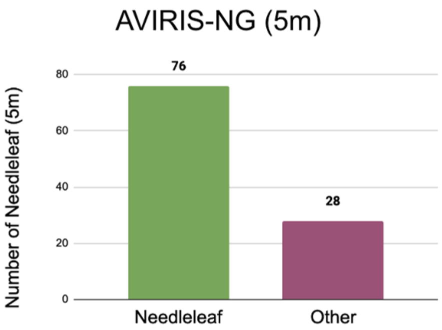
- Fraction output has a similar needleleaf vegetation pattern.
- Grass is unclassified in the fraction output

Validation Map Assessment for Needleleaf Fraction Cover



Validation map (HySpex)





73% mapped correctly

High correlation between needleleaf tree counts and needleleaf class pixels

Summary

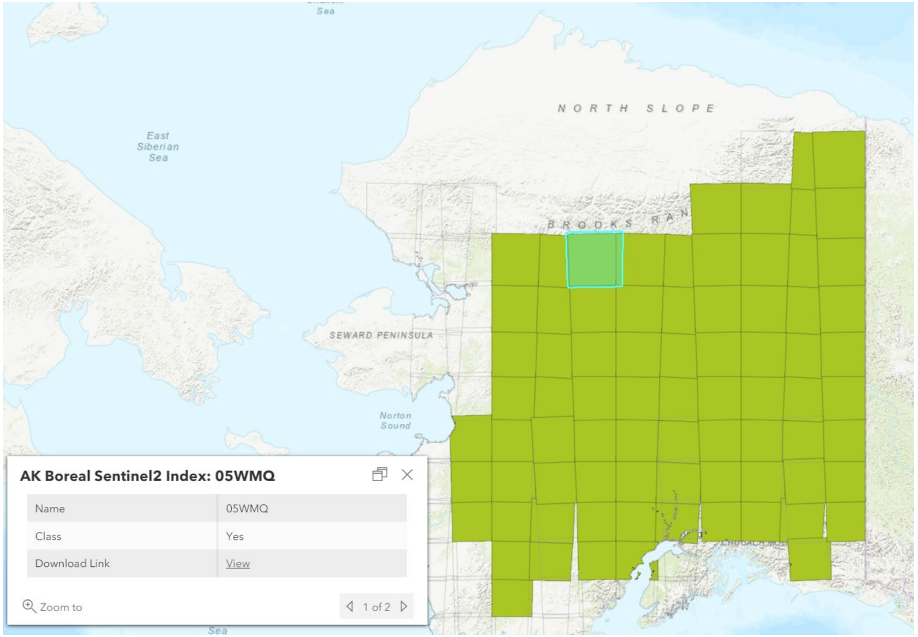
- A novel approach to simulate hyperspectral data to generate improved vegetation map for whole boreal Alaska
- High flammable needleleaf species mapping to aid wildfire management practices
- A novel approach to validate the unmixing estimates


Boreal Forest, Interior Alaska

Vegetation Maps, Boreal Alaska

StoryMap: Vegetation Maps of Boreal Alaska (Tile: 100 km x 100 km)

Green Tiles: Vegetation (.tif) file available for download

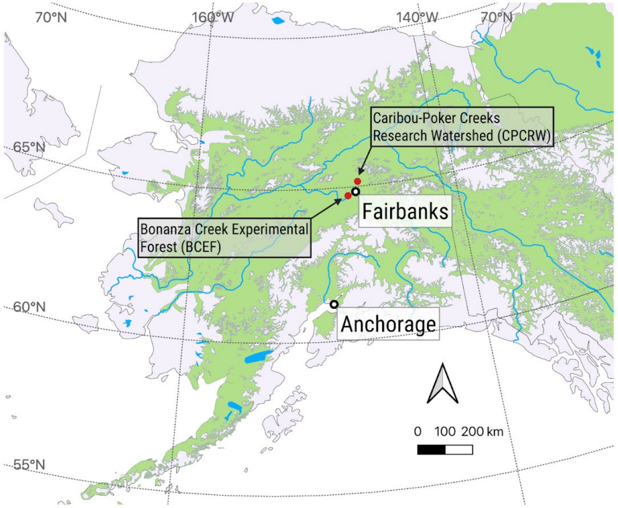


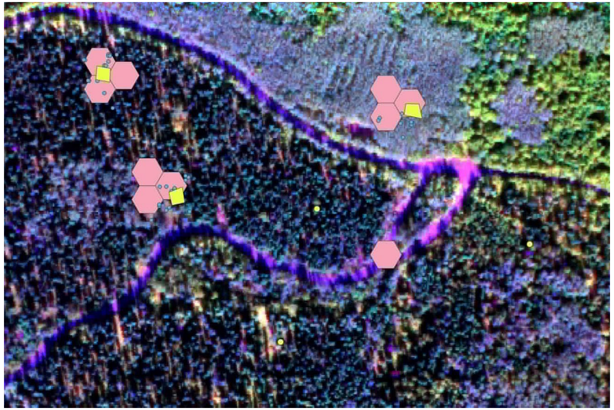
Vegetation mapping with HySpex

1m repeat imagery from field sites at CPCRW (2019 & 2020) and BCEF (2020 & 2021)

Reveals rich details in vegetation cover structure and composition. Yellow: Field plots. Blue: individual tree data. Pink: Classifier training hexagons

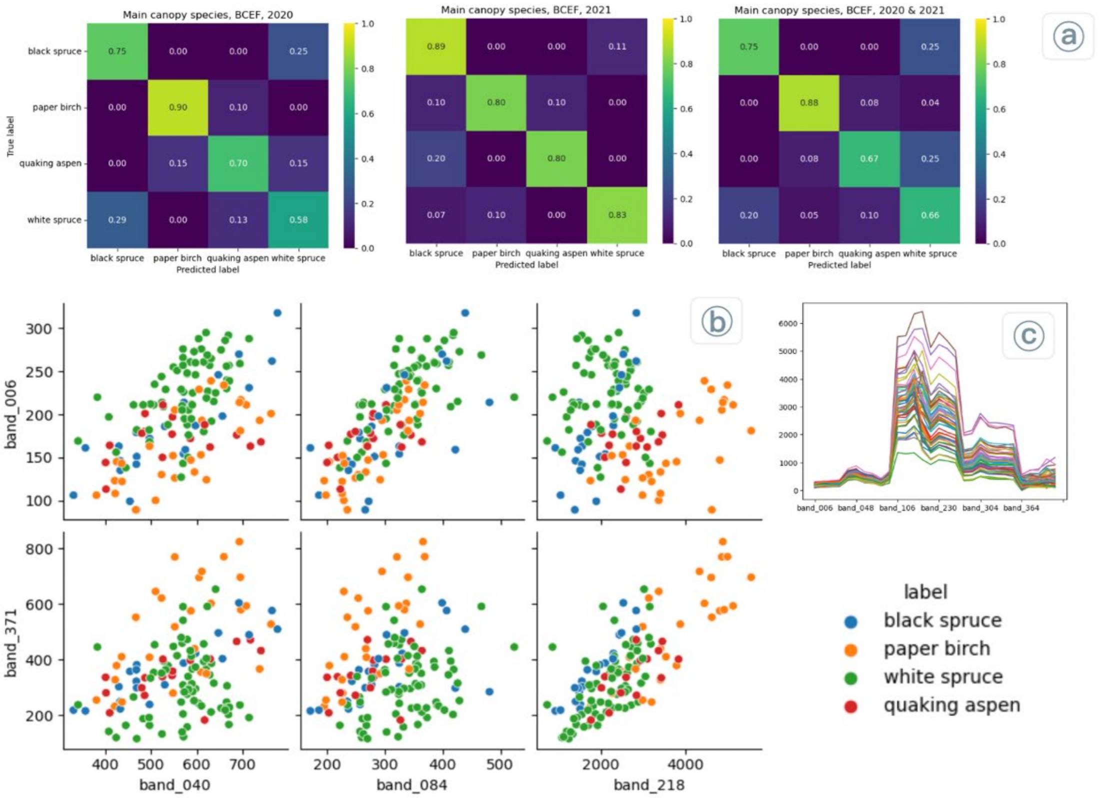
Waigl et al., in revision



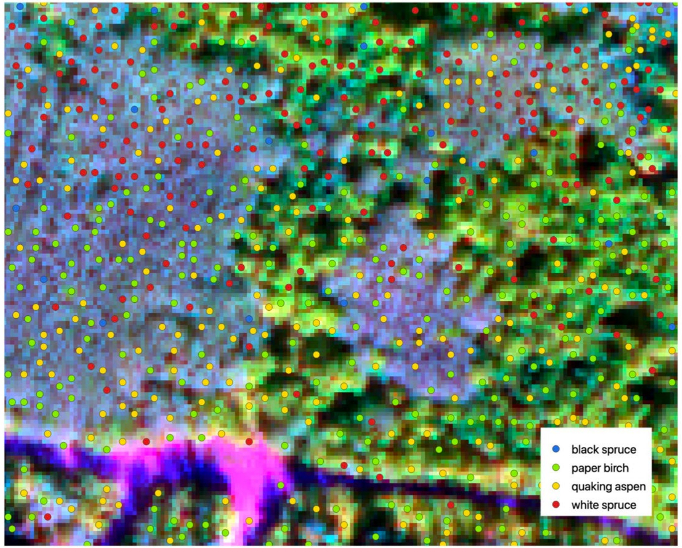


Vegetation type
Black Spruce Woodland with Tussocks
Black Spruce/Tamarack Forest
Closed Black Spruce Forest
Closed Black/White Spruce Forest
Closed Paper Birch Forest
Closed Quaking Aspen Forest
Closed Quaking Aspen/White Spruce Forest
Closed Spruce/Paper Birch Forest
Closed Spruce/Paper Birch/Aspen Forest
Closed Tall Alder Shrub
Closed Tall Birch/Willow Shrub
Closed White Spruce Forest
Open Black Spruce Forest
Open Quaking Aspen/Spruce Forest
Open Spruce/Paper Birch Forest
Open Tall Alder Shrub
Open Tall Birch Shrub
Open White Spruce Forest
Wet Sedge Meadow
Wetlands

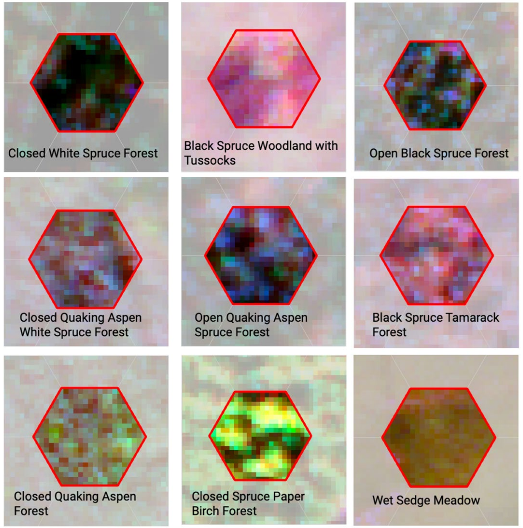
Pixel-level analysis using tree-crown detection and pixel spectra



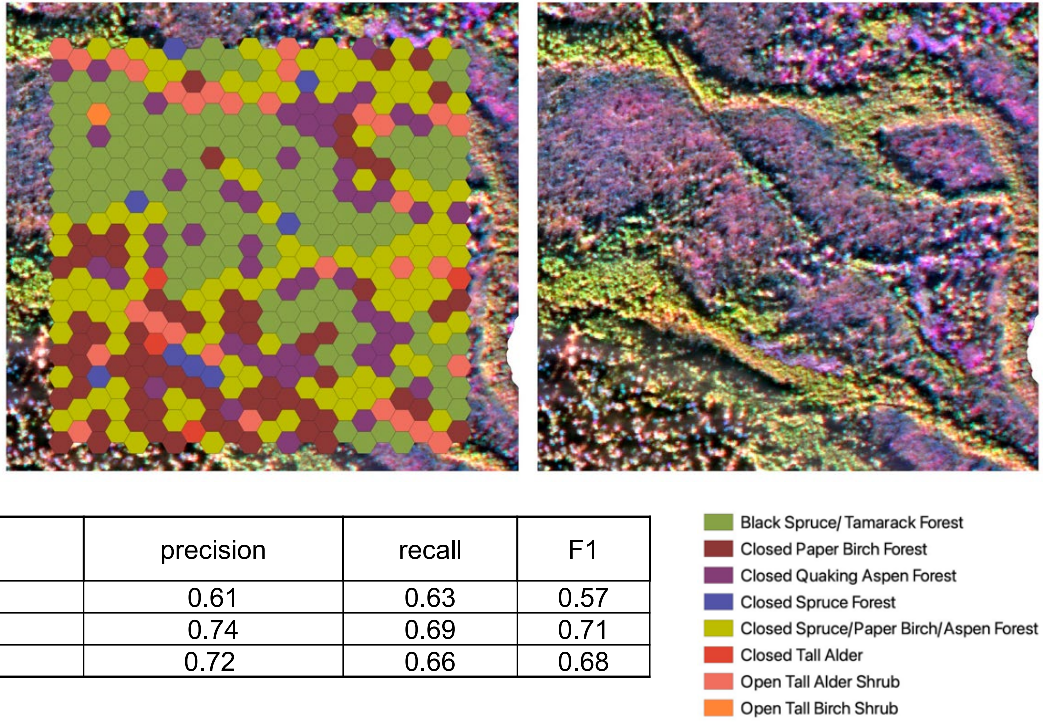
- Discriminate black / white spruce, paper birch and quaking aspen
- Simplified spectra after band correlation analysis



Stand-level analysis with hexagonal aggregates



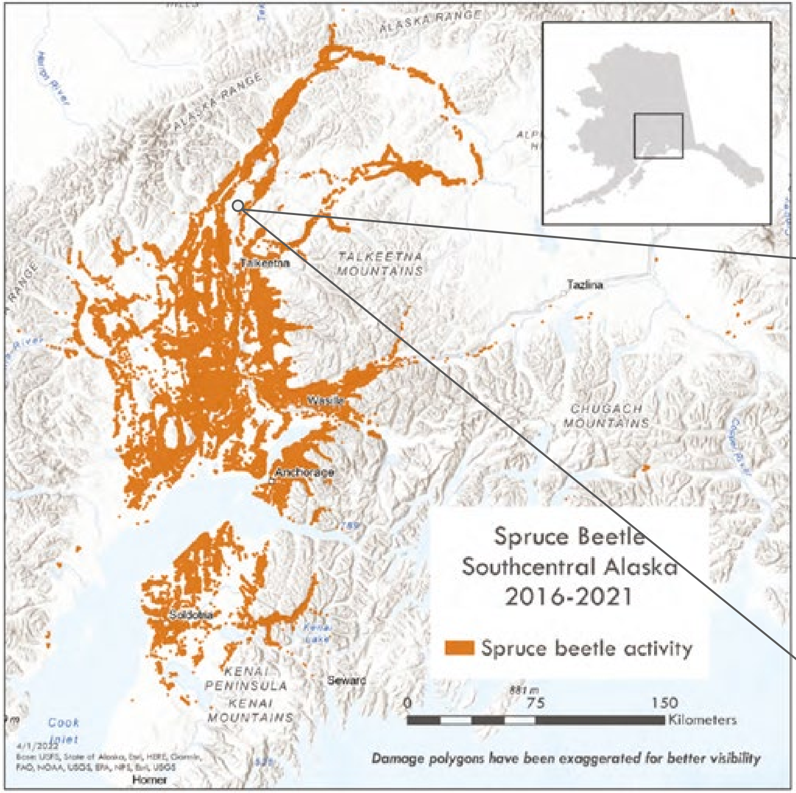
We move from pixel to stand scale by using a hexagonal grid

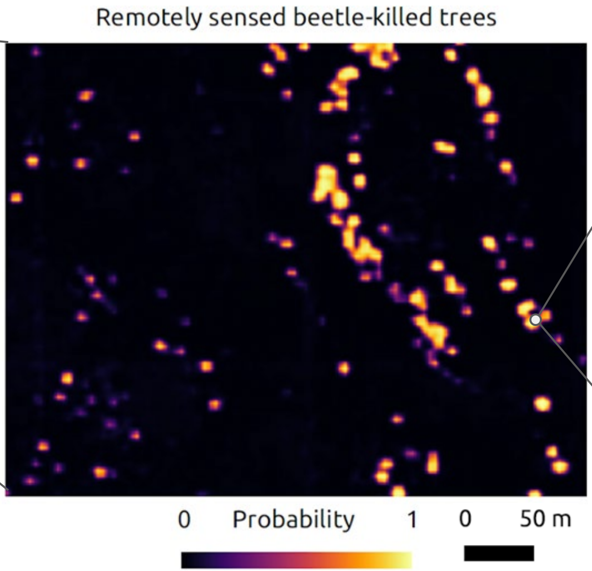


	precision	recall	F1
BCEF 2020 (cross-validation)	0.61	0.63	0.57
BCEF 2021	0.74	0.69	0.71
CPCRW 2019	0.72	0.66	0.68

Changing fuel conditions: spruce beetle

Filling data gap:
Extent and density of beetle-killed trees





Fettig et al.

Zwieback et al., in prep

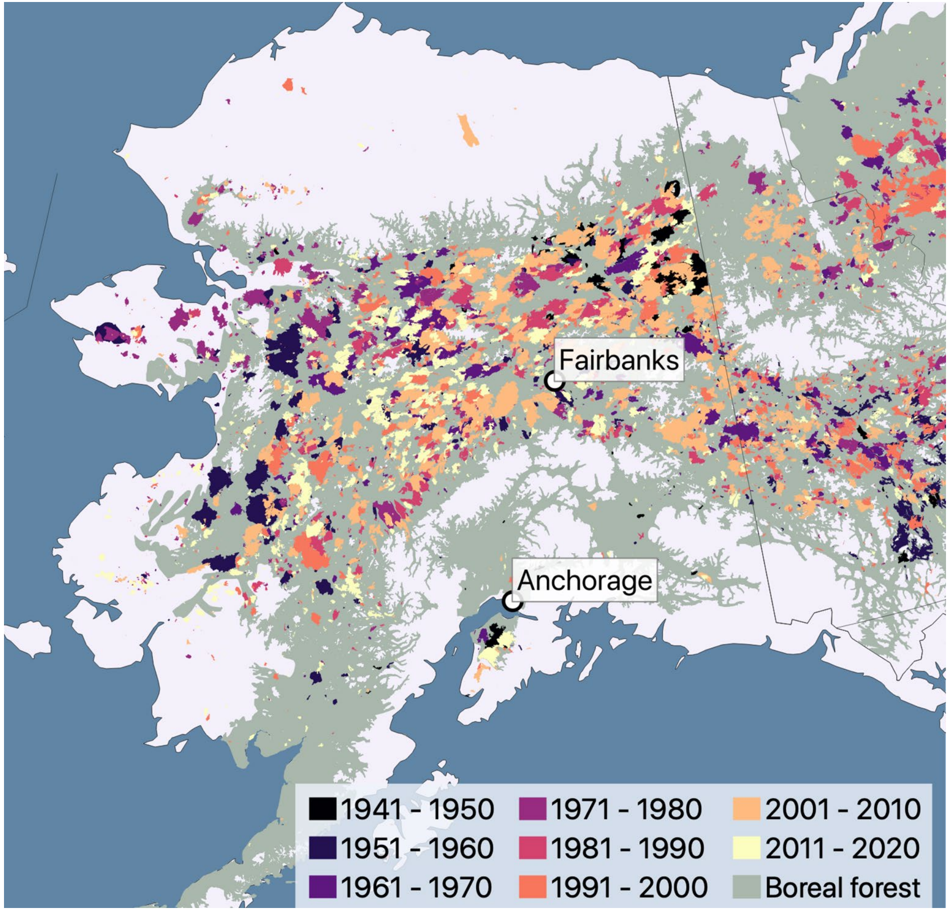
Investigating large scale climate variability links to Alaska wildland fire

Decadal scale patterns of fire perimeters suggest that low-frequency climate variability is linked to fires!

Q: What are the climate drivers of wildland fire in Alaska?

Q: Is there predictability of these drivers?

Q: Do our current dynamical forecasts provide skill for wildland fire? What needs to be improved in the models?



Fires in Alaska, 1940–2020

Fire Weather Predictability [FiWePs] group

- Group to tackle “What are the observed climate drivers of wildland fire in Alaska and can they provide predictability at the seasonal scale?”
- Multi-pronged approach with early career researchers, students and fire managers.


Tom Ballinger


Rick Lader

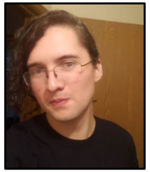

Uma Bhatt


Peter Bieniek


Elizabeth Fischer


Chris Waig


Cecilia Borries-Strigle


Joshua Hostler


Eric Stevens

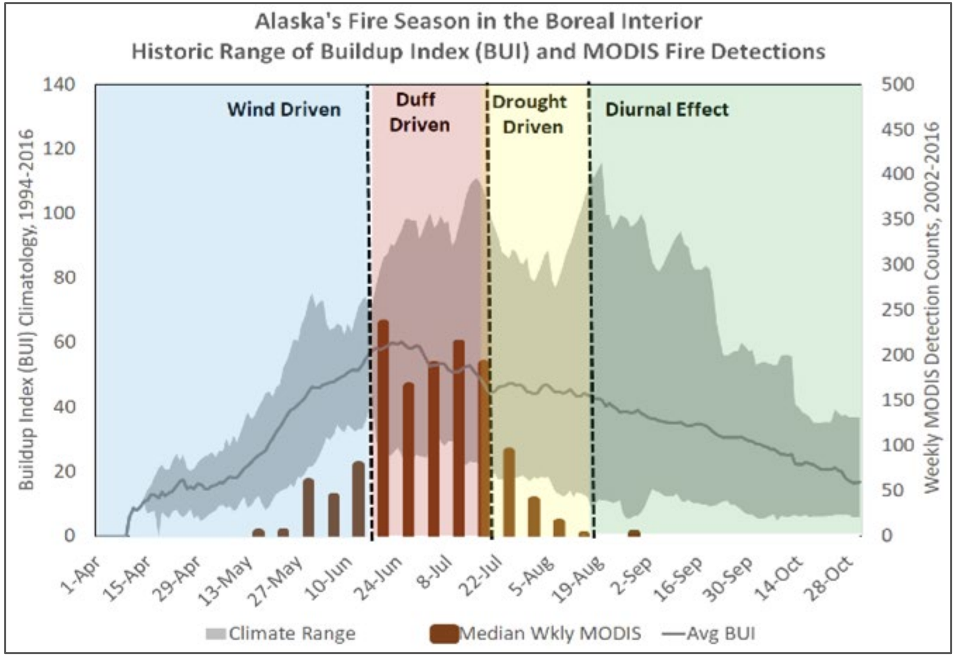

Heidi Strader


Rick Thoman

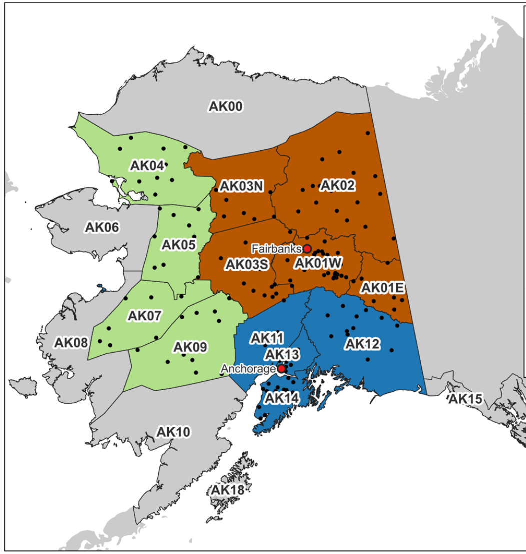
Start of season	During the season		End of season
Snowmelt timing Lead: P. Bieniek	June/July temperature and precipitation Lead: T. Ballinger/R. Lader	Lightning Lead: J. Hostler	Timing of August rains Lead: R. Lader

- Statistical analysis of observational and model data
- Evaluate the atmospheric drivers of each driver of the wildfire season including: teleconnectons (e.g. El Niño, PDO), weather map patterns

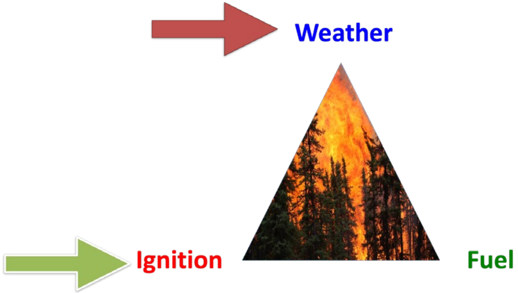
Peak of Fire Season Typically Occurs during Duff-driven Subseason



Seasonal evolution of BUI in interior Alaska (gray line).



Predictive Service Area	Code
North Slope	AK00
Tanana Valley-East	AK01E
Tanana Valley-West	AK01W
Upper Yukon Valley	AK02
Tanana Zone-North	AK03N
Tanana Zone-South	AK03S
Koyukuk and Upper Kobuk	AK04
Middle Yukon	AK05
Seward Peninsula	AK06
Lower Yukon	AK07
Yukon-Kuskokwim Delta	AK08
Kuskokwim Valley	AK09
Bristol Bay and AK Peninsula	AK10
Susitna Valley	AK11
Copper River Basin	AK12
Matanuska Valley and Anchorage	AK13
Kenai Peninsula	AK14
Northern Panhandle	AK15
Central Panhandle	AK16
Southern Panhandle	AK17

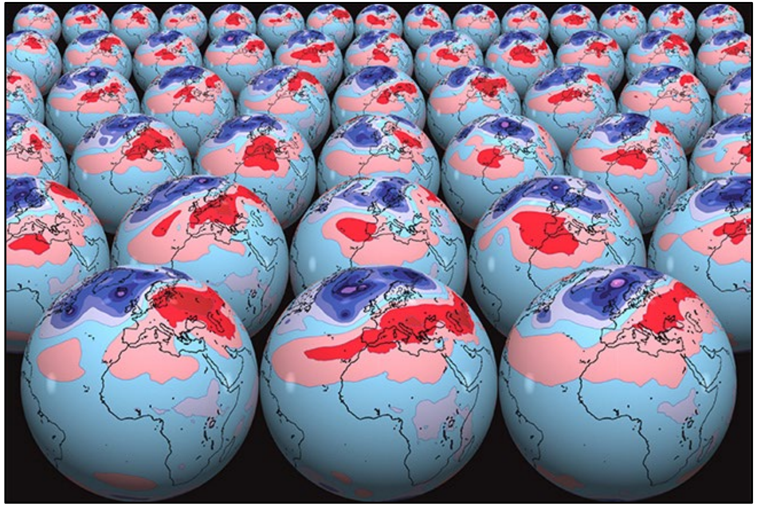


Using Seasonal Forecasts to Create Summer Fire Outlooks

- Seasonal forecasts from three dynamical climate models:
    - NOAA CFSv2
    - ECMWF SEAS5
    - Météo France Sys 8
    - Combined into multi-model ensemble (better skill)

- To calculate BUI, forecasts of:
    - Temperature
    - Precipitation
    - Humidity

- Forecasts initialized in:
    - March
    - May

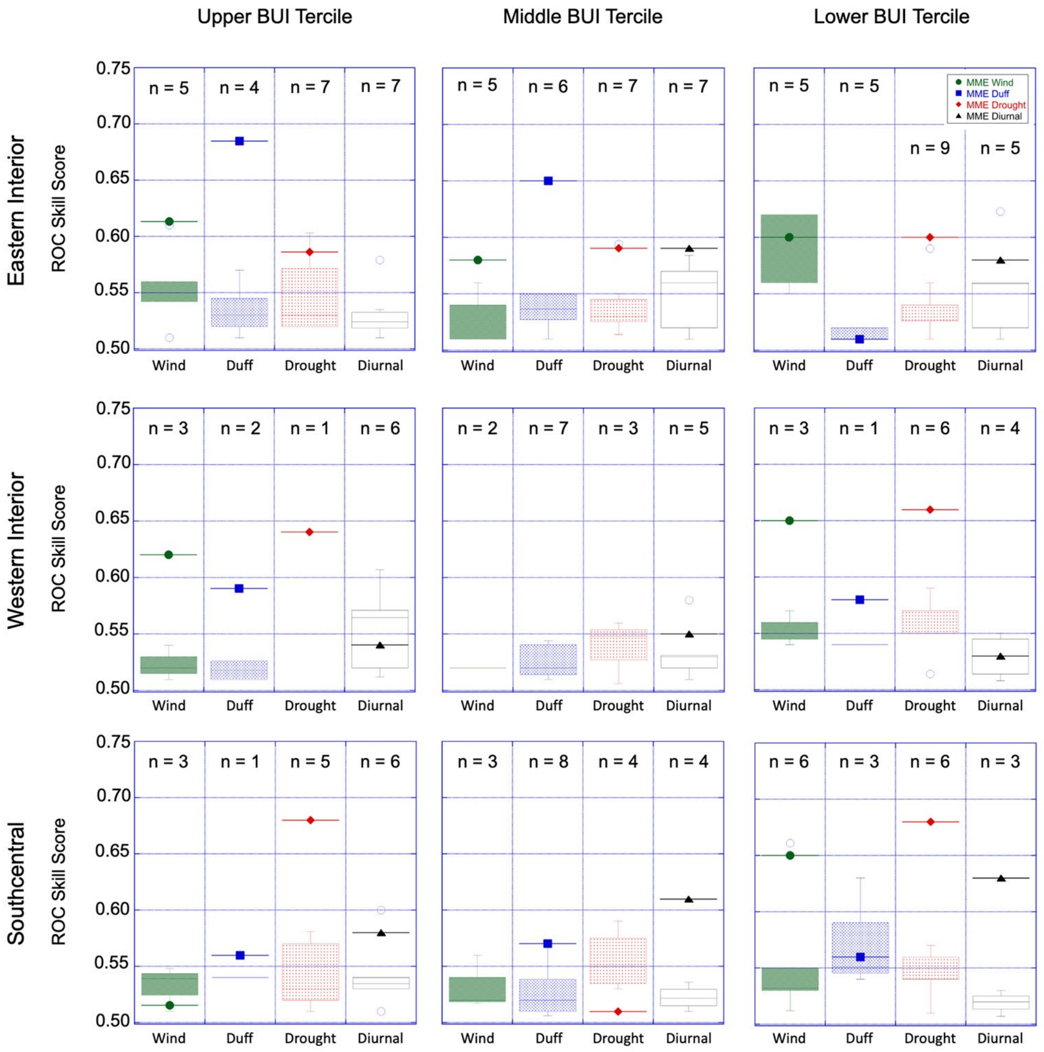


Ensemble forecasting.

https://www.ecmwf.int/en/about/media-centre/focus/2017/fact-sheet-ensemble-weather-forecasting

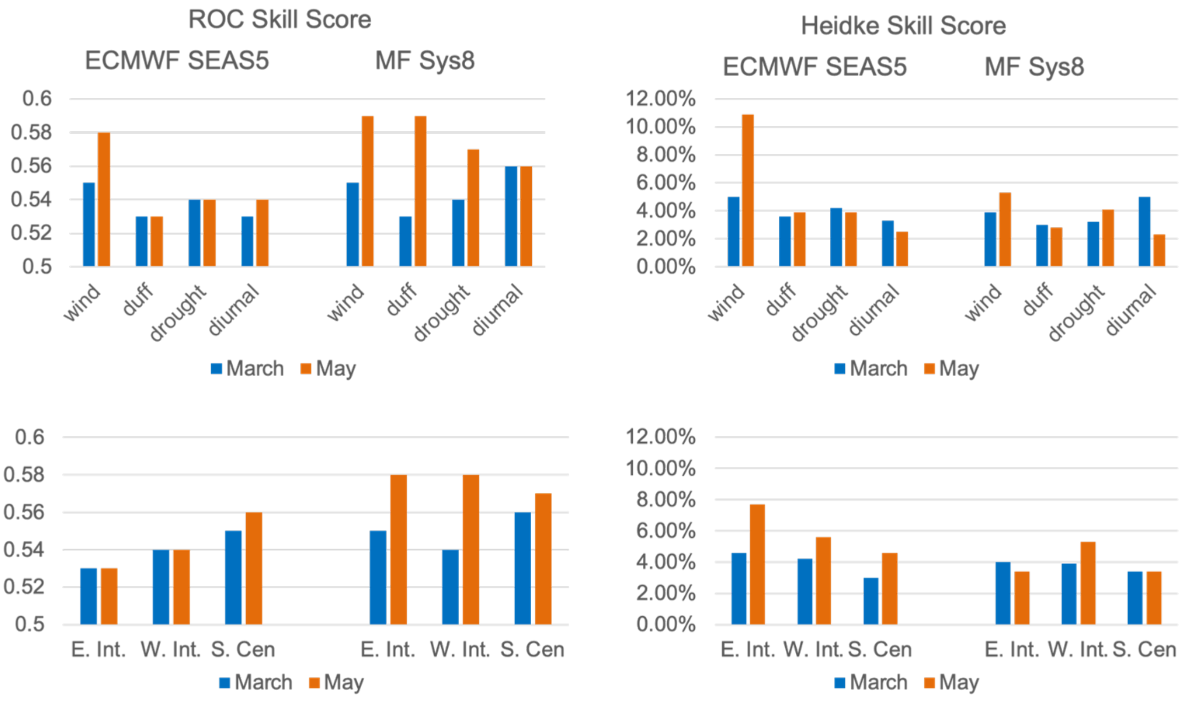
March-Initialized Seasonal Forecasts Show Skill at 3-Month Lead

- Skill varies by BUI tercile, fire subseason, and Alaska subregion
- Skill increases in multimodel ensemble



ROC skill scores for each BUI tercile, fire subseason, and Alaska subregion.

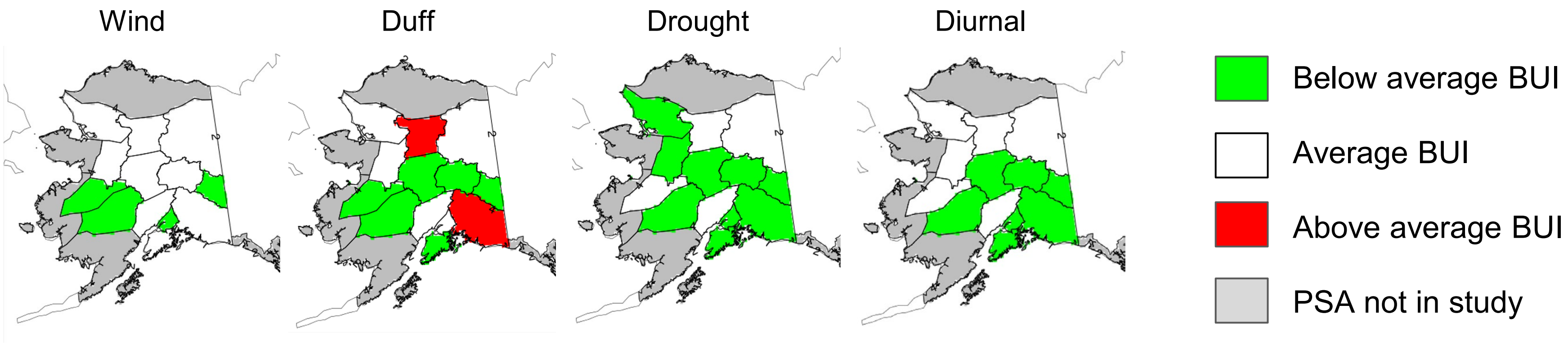
May-Initialized Seasonal Forecasts Have Same or Greater Skill Compared to March-Initialized Forecasts



ROC and Heidke skill scores for March and May forecasts.

- ~One month before the peak of the fire season
- Request by fire managers to help determine land conversion for rest of fire season

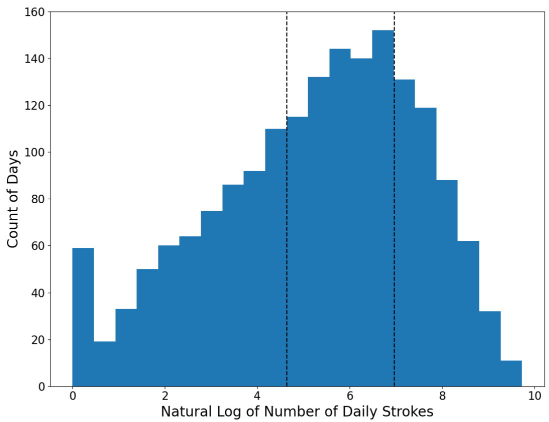
What Other Pieces Do We Need to Create an Operational Product?

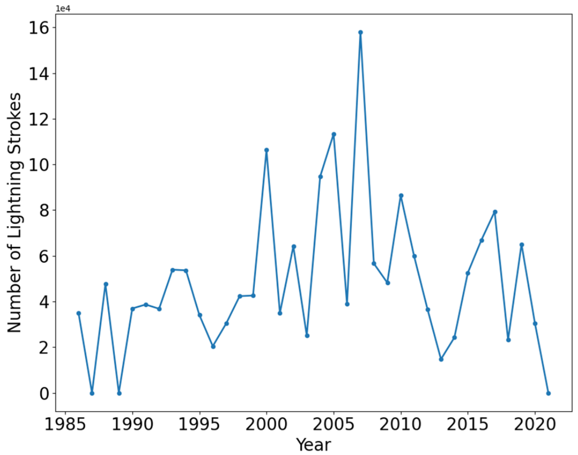


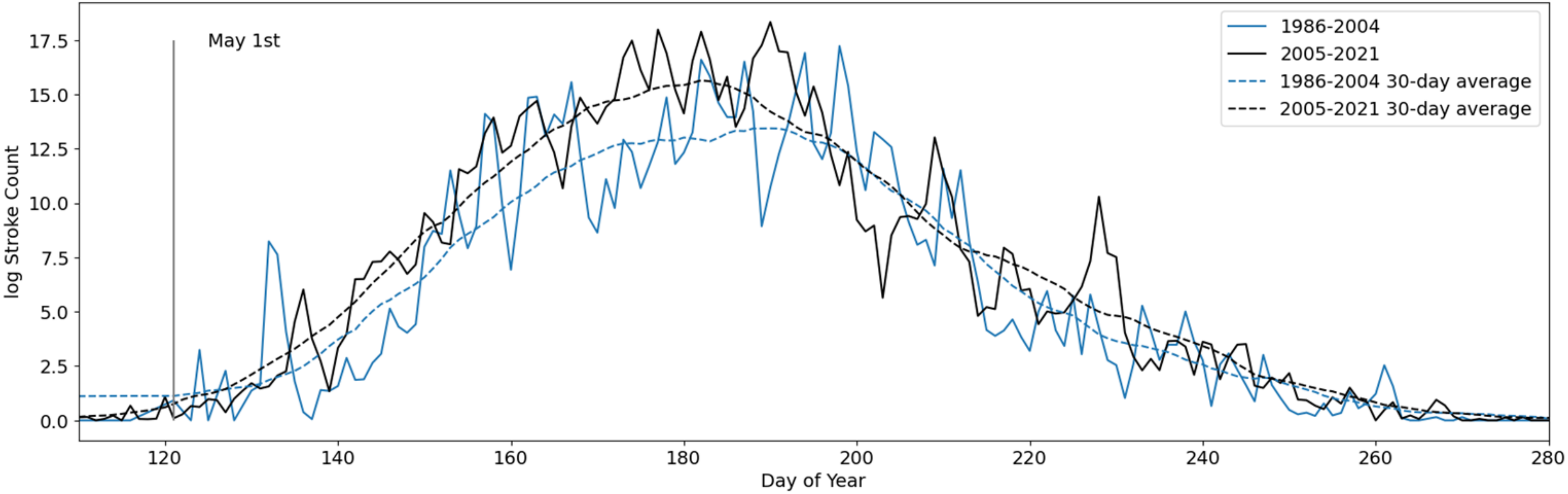
2022 MME BUI forecast by fire subseason presented to fire managers in March 2022.

- Systematic evaluation of seasonal forecasts for Arctic regions
  ➞ Additional post-processing of variables to increase forecast skill
- Combination of statistical forecasts (March) and dynamical forecasts (May)

Lightning In Eastern Interior Alaska

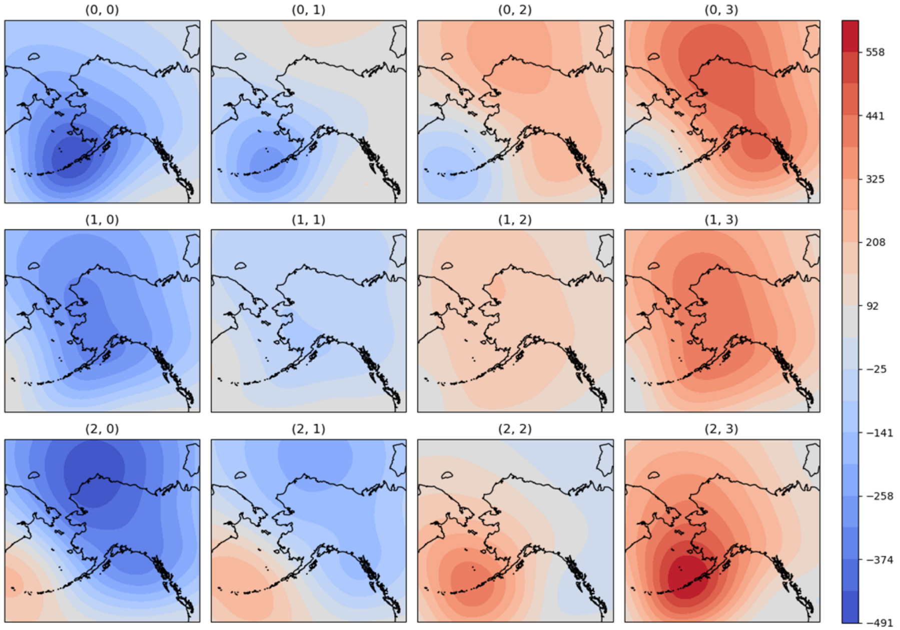




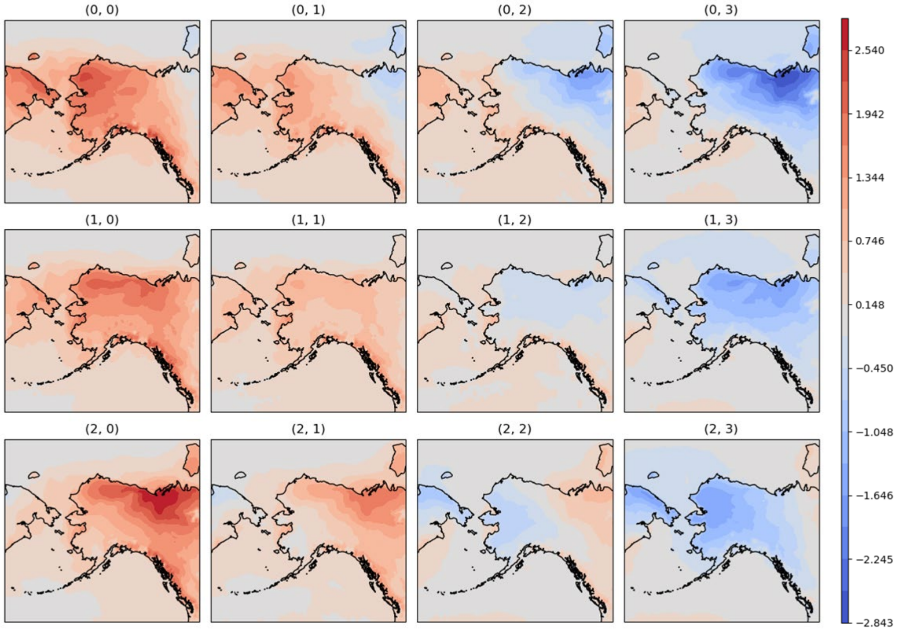


Self-Organizing Maps Connect Climate and Meteorology

500 hPa Height Anomaly

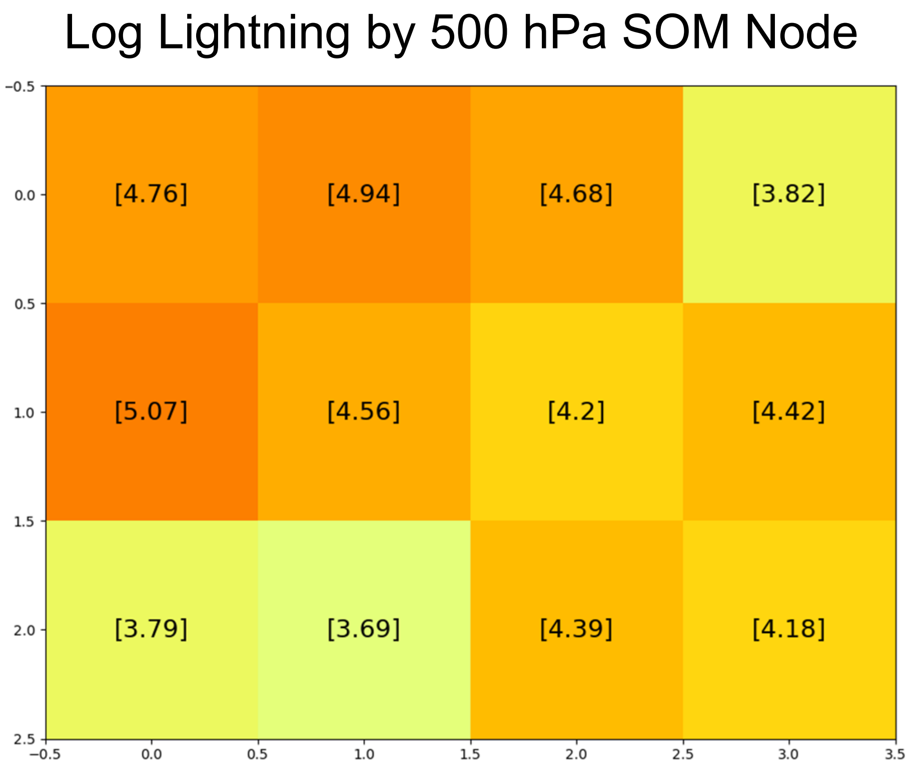


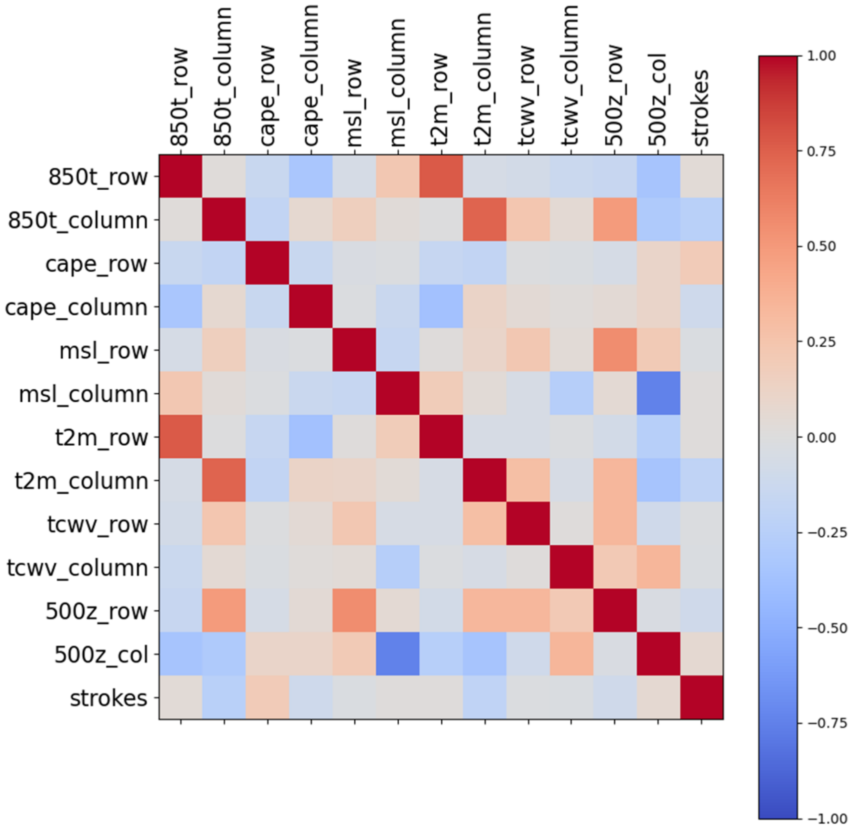
2m Temperature Anomaly



Daily anomalies for June-July from 1959-2022 ERA5.

From SOMs to Random Forest Classifier





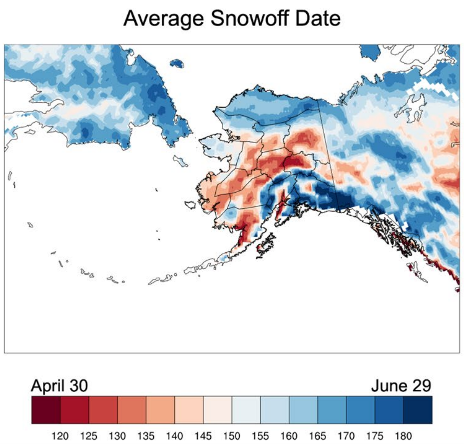
Random Forest Classification Results

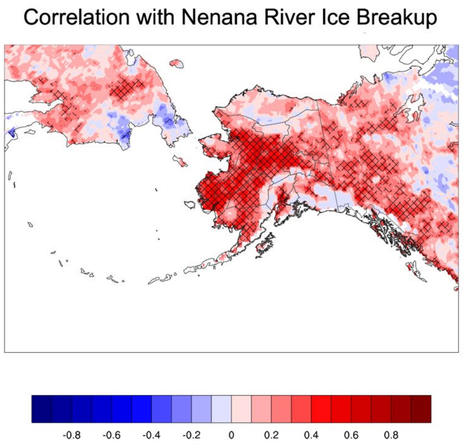
- AUROC scores above 0.5 and F1-scores above 0.33 indicate outperforming naïve classification strategies.
- Model reasonably distinguishes high and low lightning days while having trouble distinguishing the middle class from its neighbors.
- Low lightning days perform best in precision while high lightning days boast better recall.

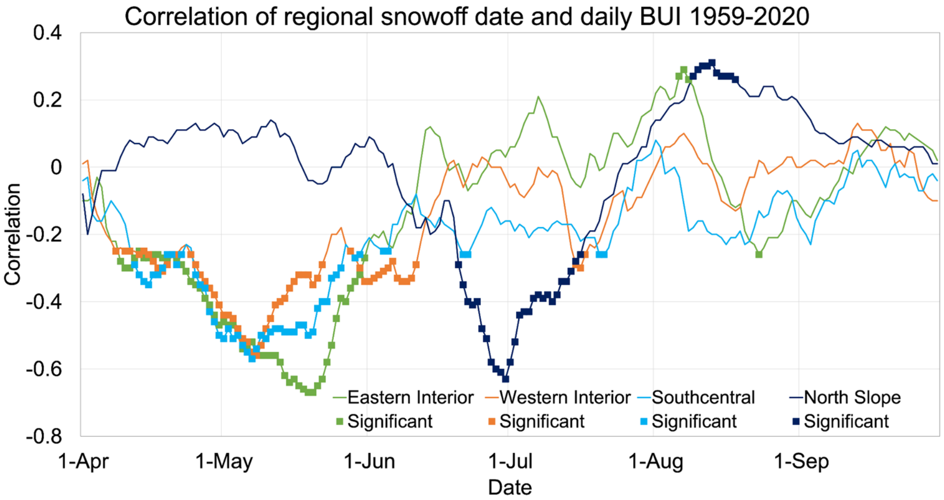
		Predicted		
		Low	Middle	high
Actual	Low	73	28	24
	Middle	34	37	47
	High	12	19	81

Class	Precision	Recall	F1-Score	AUROC
Low	0.613	0.584	0.598	0.767
Medium	0.440	0.314	0.366	0.559
High	0.533	0.723	0.614	0.785
Mean	0.529	0.540	0.526	0.704

Earlier snowmelt results in higher early season BUI





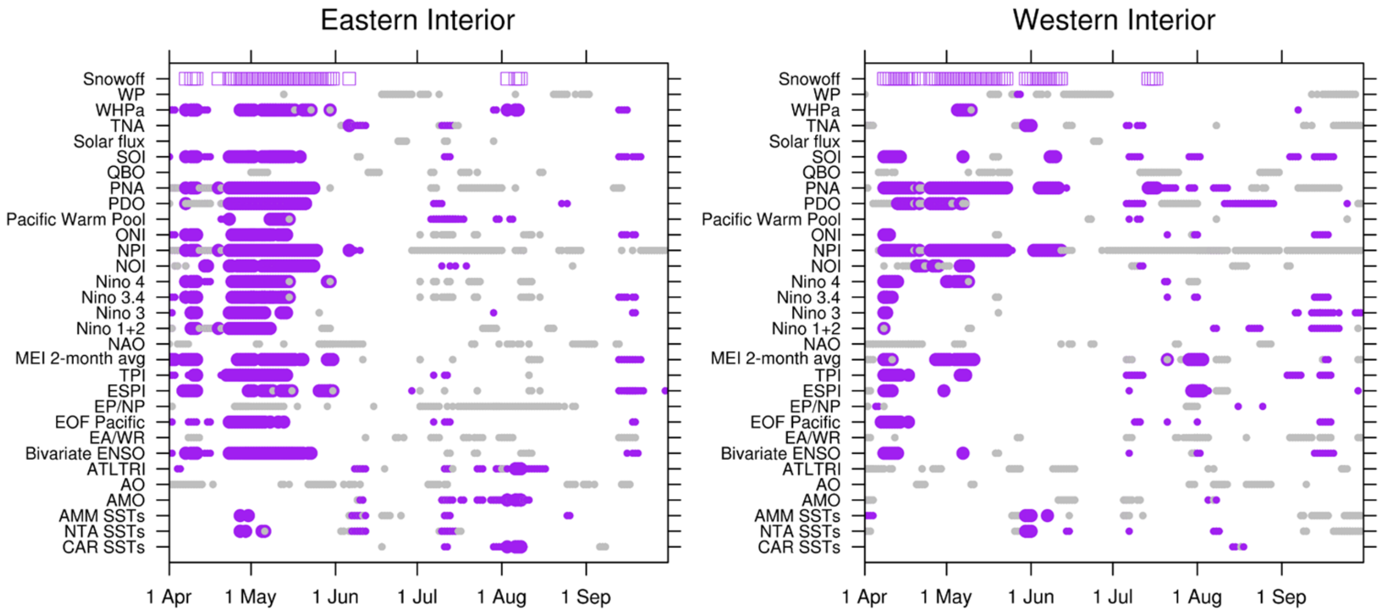


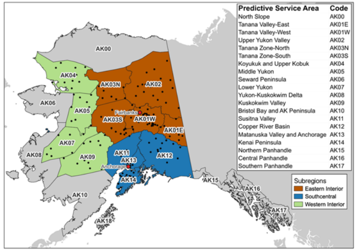
- Snowmelt marks the start of the Alaska fire season in April-May
- The date of snowmelt (snowoff) each spring was derived using the ERA5 reanalysis for 1959-present
- Snowmelt timing is tied to river ice breakup date in Interior Alaska
- Breakup date in Alaska is known to occur earlier during El Niño conditions (Bieniek et al. 2011) that offers potential predictability
- Higher BUI early in the season linked with earlier snowmelt, weaker relationship later in the season

Peter Bieniek

Snowmelt date correlated with teleconnections

Teleconnections and snowoff 95% significant correlations with daily BUI





- Many teleconnections linked with BUI and snowoff in the early wildfire season
- Relationships vary somewhat by region

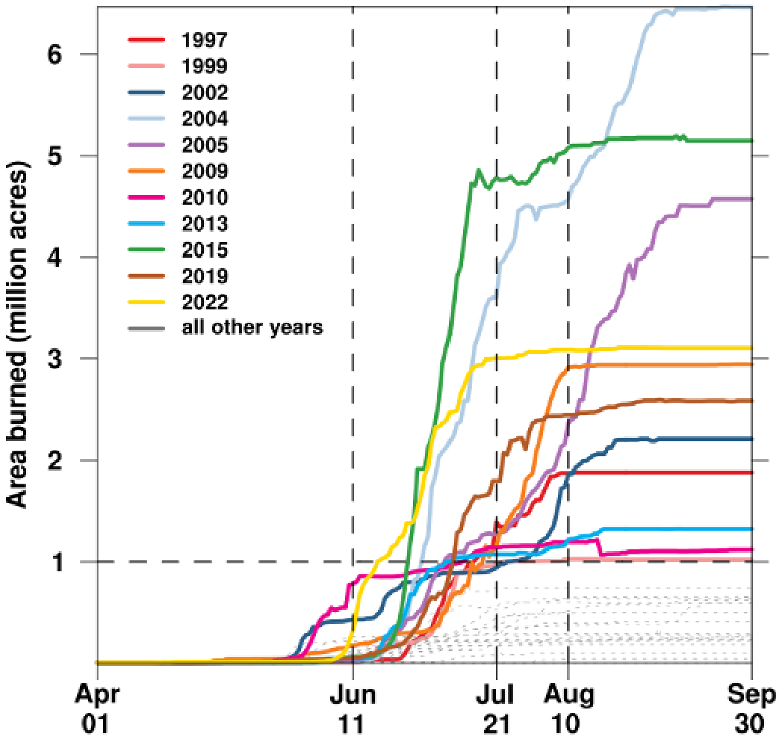
Peter Bieniek

Severe fire years = 1 million+ acres burned

- 11 of the past 30 wildfire seasons (1993-2022) in Alaska have been severe with 1M+ acres burned.

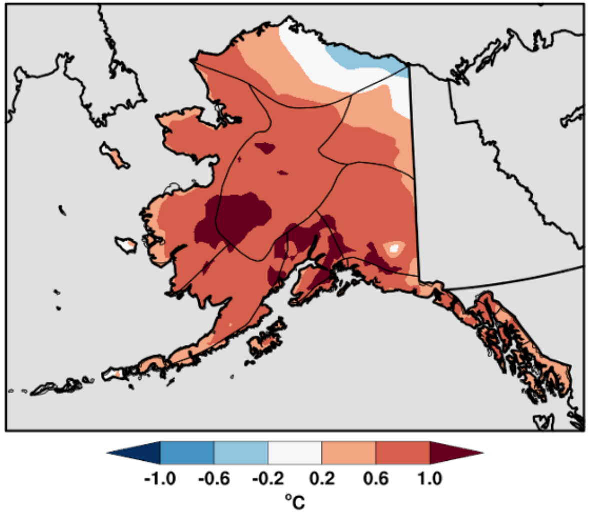
- The vast majority of wildfire activity occurs during two subseasons:
  - Duff (June 11 - July 20)
  - Drought (July 21 - August 9)

- ***Normally***, mainland Alaska transitions to westerly flow in late-July/early-August, allowing cool, moisture-laden air to move across the state and effectively shut down the fire season.

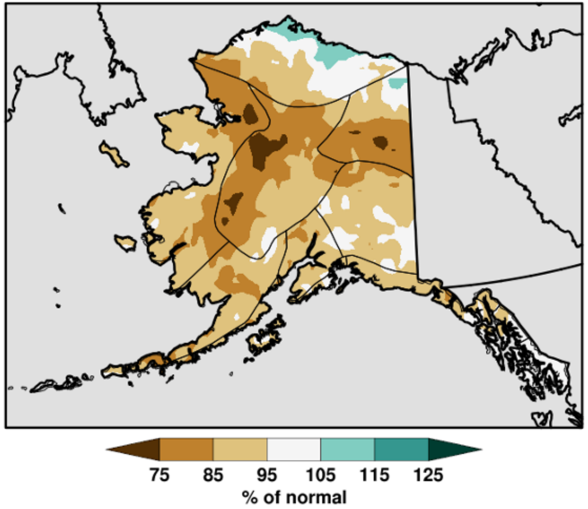


Duff season (June 11 - July 21) anomalies
1M+ acre seasons vs. 1993-2022 climatology

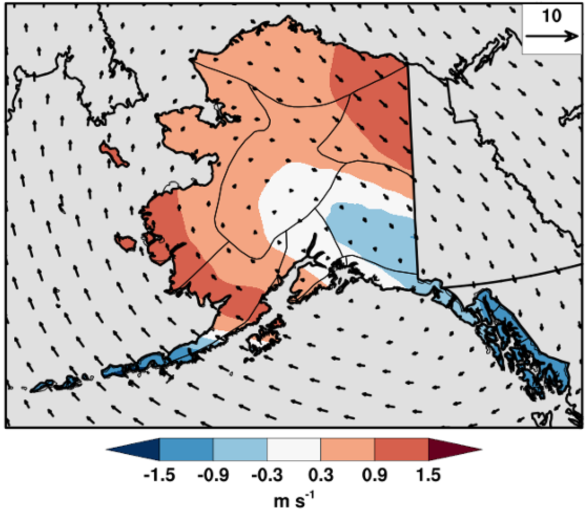
Temperature



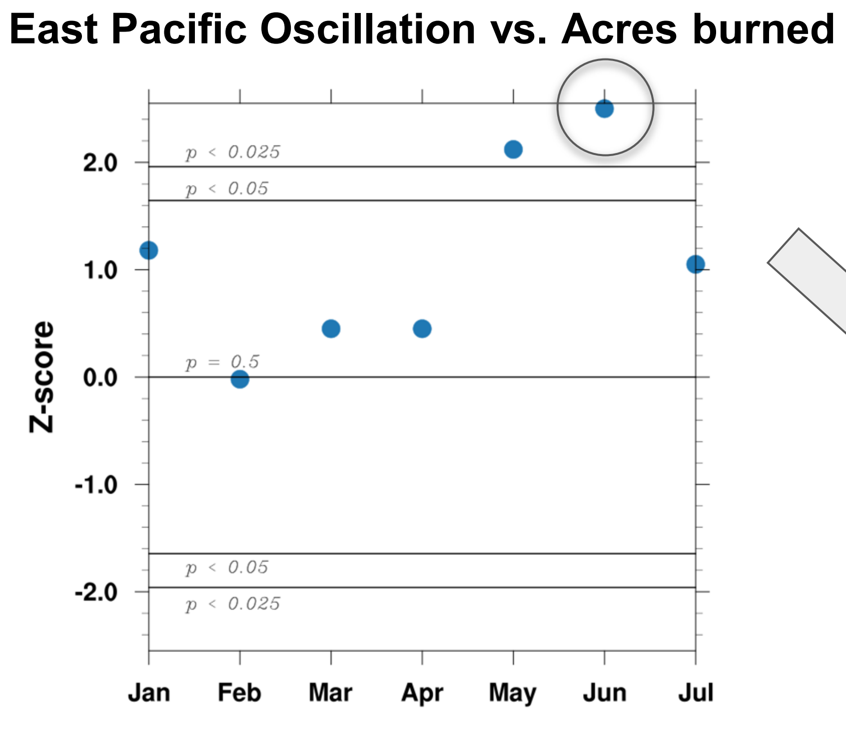
Precipitation

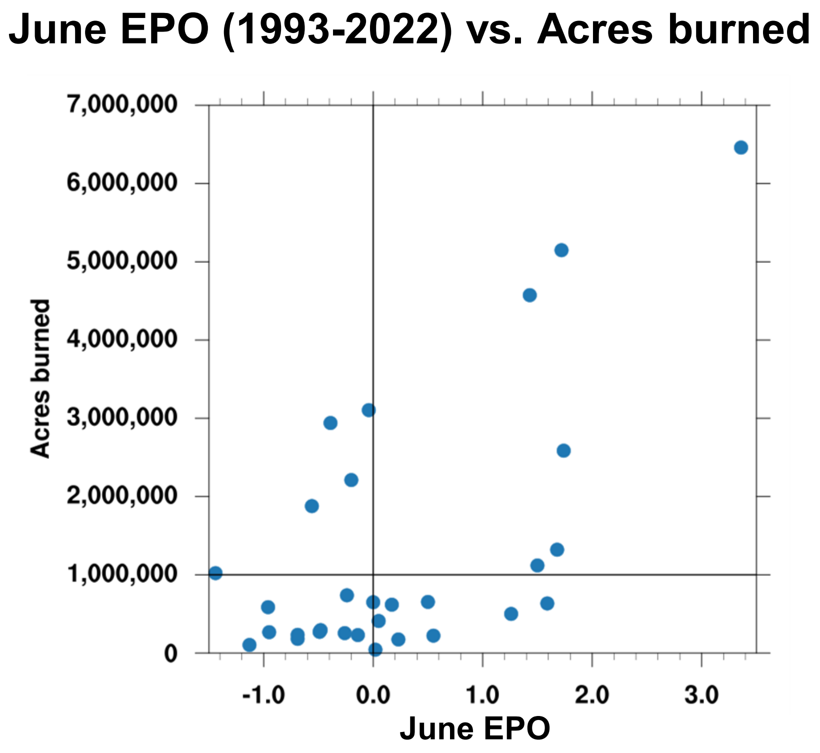


500-hPa wind



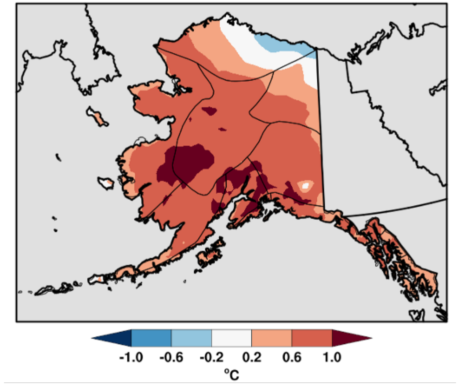
Correlations between acres burned and monthly teleconnection indices show significant relationships



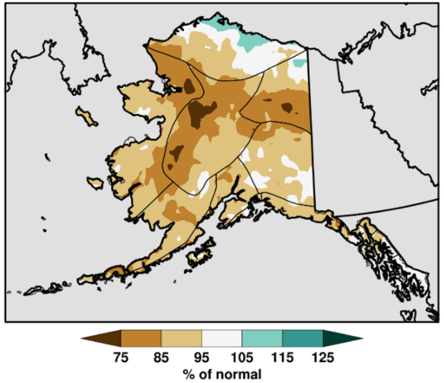


Duff season anomalies in 1M+ acre seasons

Temperature

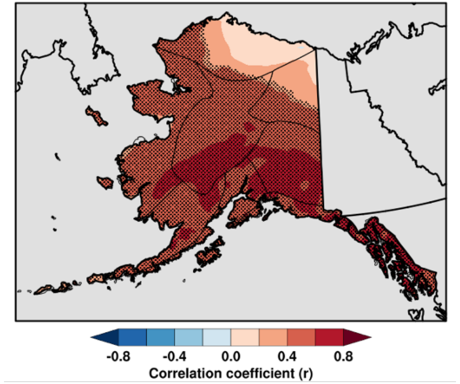


Precipitation

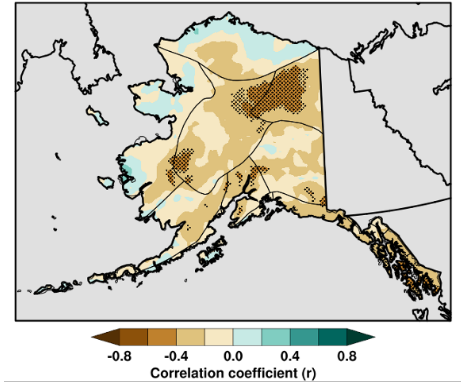


Correlations with June East Pacific Oscillation

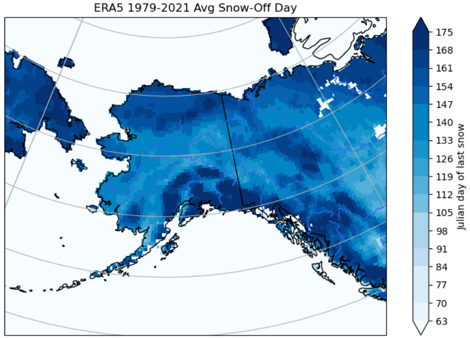
Temperature

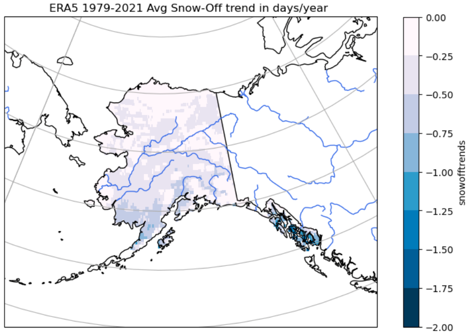


Precipitation



Machine learning to understand seasonal fire weather

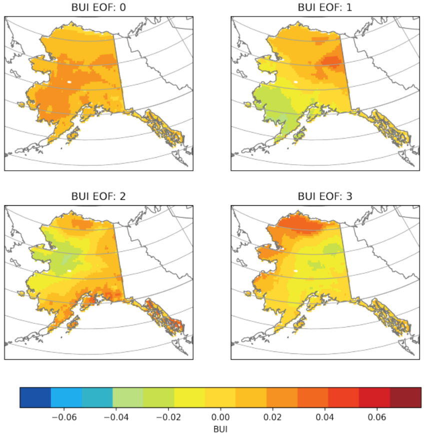


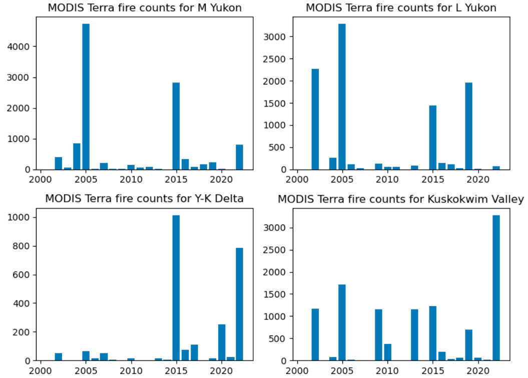


Machine learning

Predictability analysis

Empirical Orthogonal Functions avg. BUI, for each fire subseason (wind, duff, drought, diurnal effect)





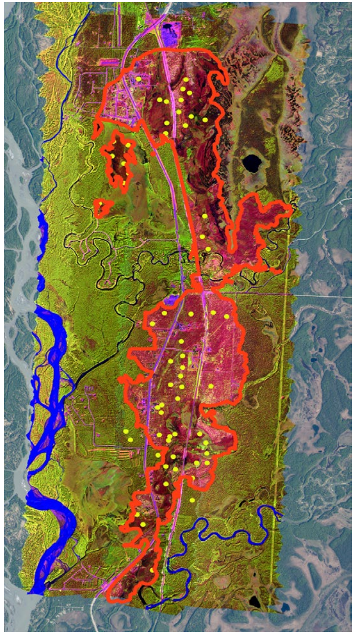
predictor variables (eg. fire weather climatology in wind/duff/drought/diurnal sub-season, last day of snow...)

target variables: gridded annual fire activity (eg. percentage of grid cell burned), seasonal BUI

Chris Waigl -ML

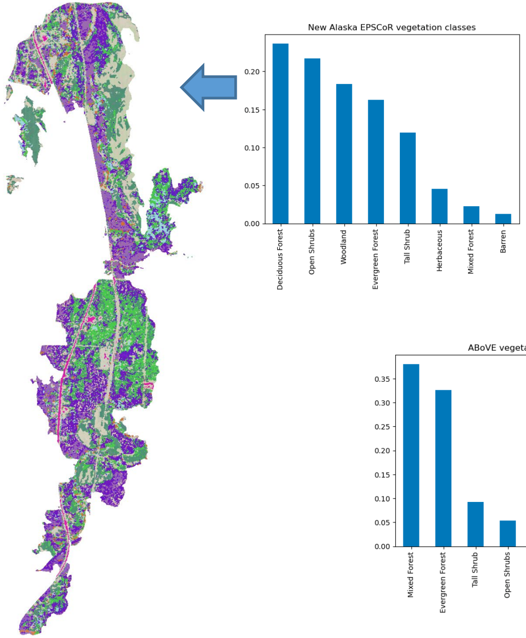
McKinley burn remote sensing synthesis

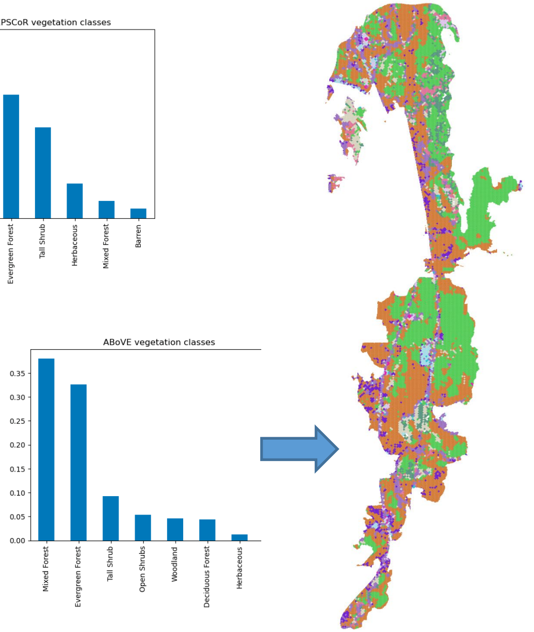
Team: Chris Waigl, Heather Greaves, Jen Schmidt, Matthew Berman



Question 1:
Can we model burn status? Which predictors are most important? (400m perimeter of building)

Question 2:
Can we predict over- and understory burn severity?





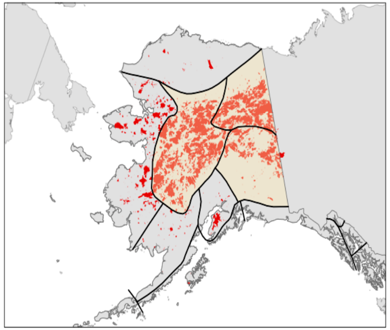
Badola et al. fuels

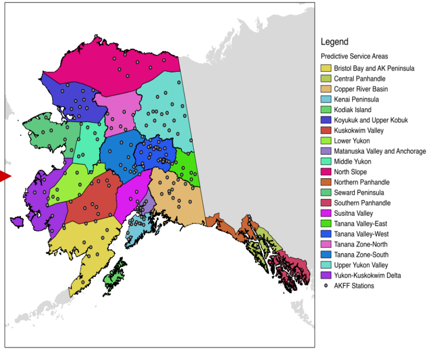
NASA ABoVE 2014 fuels

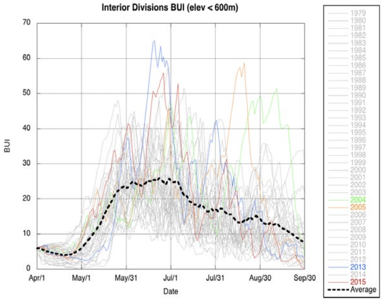
Synthesis paper - reflect on the process

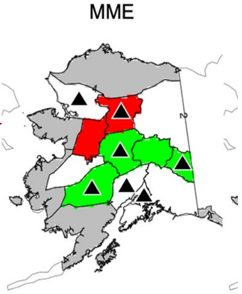
Ongoing engagement with end users is key to actionable science

- Role for boundary organization: Alaska Fire Science Consortium
- Introduced end users (fire managers, fire weather forecasters) to the project
- Regular bi-weekly meetings of project open to end users provided easy way to engage THROUGHOUT the research process
- Used seasonal management workshops to raise awareness, report progress, and get feedback from larger group of end users
- Document our insights into this process









Highlights since last all-hands

- Promotions & New Jobs
- Conferences, Publications & Grants funded
- Progress on Yankovich Burn Interpretive site

Yankovich Interpretive Trail and fire effects monitoring

AGU Presentations

Final Year Activities

- Publications
  - Many
- Data archiving
  - Data to be archived
  - Planning/understanding process
  - Working to make it usable by others
- Next funding applications
  - High latitude predictability research

Axiom
DATA SCIENCE

Conclusions

- Key ecosystem services are demonstrating immediate resilience to wildfires, but important exceptions exist.
- Social and ecological characteristics are associated with wildfire damage of property in the Wildland-Urban Interface.
- Seasonal forecasting of BUI using dynamical models show limited skill at leads of 3-5 months and greater skill at 1-2 month leads. The FiWePs teleconnections analysis suggests using statistical models for forecasts needed for planning.
- Statistical analysis suggests large-scale climate (teleconnection indices) provides predictability for end of snow and start of seasonal rains.
- Fuels remote sensing research has matured to integrate various datasets spanning spatio-temporal scales to provide a more holistic view.
- Novel approach leveraging the Sentinel 2 satellite imagery to simulate hyperspectral data for improved boreal Alaska vegetation/fuel maps.

Acknowledgements: This material is based upon work supported by the National Science Foundation under award #OIA-1753748 and by the State of Alaska.