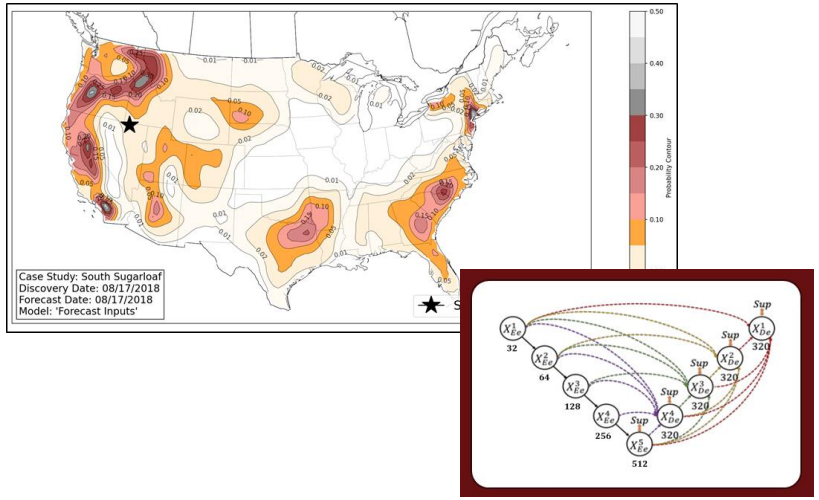
CIWRO/SPC Activities in Fire Weather Research

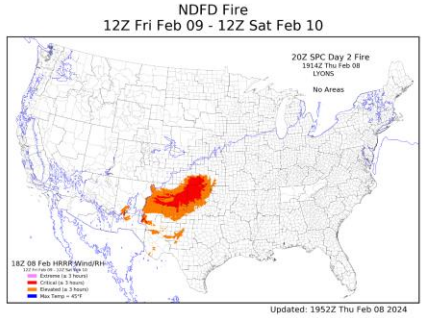
David Jahn[1,2], David Harrison[1,2], Bethany Earnest[1,3], Evan Bentley[2], Patrick Marsh[2], Israel Jirak[2], Matt Elliott[2], Amy McGovern[3], Chris Karstens[2]

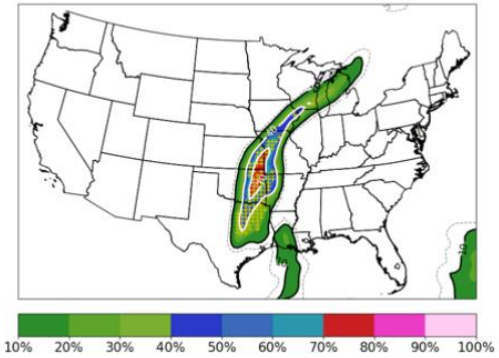
[1]Cooperative Institute for Severe and High-Impact Weather Research and Operations/University of Oklahoma

[2]Storm Prediction Center/National Weather Service/NOAA

[3]OU School of Computer Science

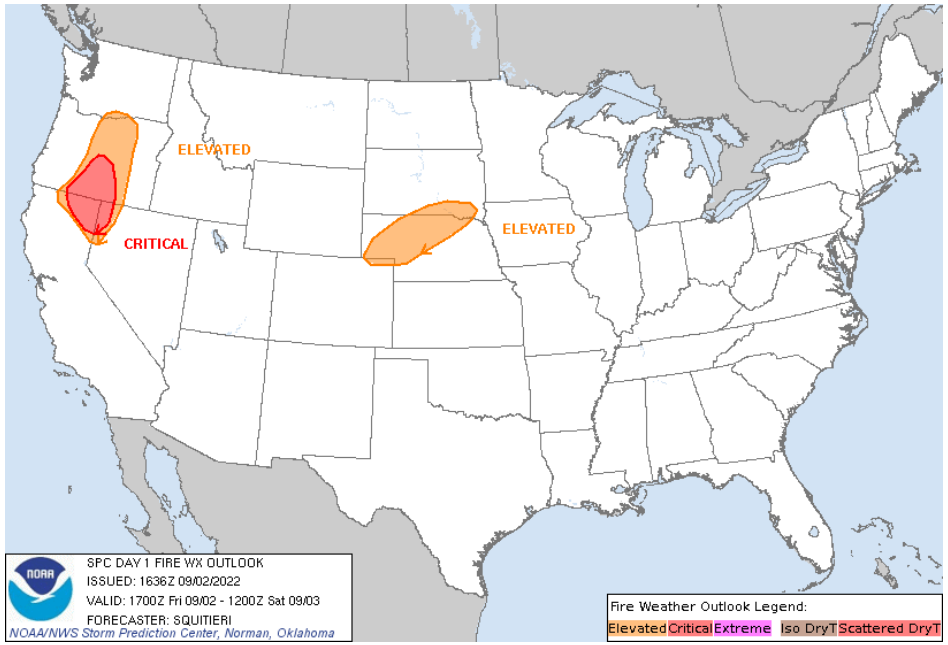






CIWRO/SPC Mission in Fire Weather Research

Support SPC forecasters in their operational duties for the generation of fire weather outlooks.



SPC Fire Weather Outlook

SPC Mesoscale Assistant/ Fire Weather Forecasters:

Evan Bentley
Andrew Lyons
Andrew Moore
Brian Squitieri
Emily Thornton
Harry Weinman
Nathan Wendt

New Fire Weather SOO! Nick Nauslar

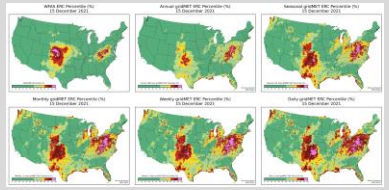
Fire Management and Risk Perception Through an Organizational Lens

Evan Bentley NOAA/NCEP Storm Prediction Center

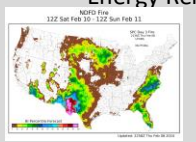
SPC Fire Weather Outlooks are intended to delineate areas of the contiguous U.S. where pre-existing fuel conditions, combined with forecast weather conditions during the next 8 days, will result in a **significant** threat for the ignition and/or spread of wildfires. This product is intended for use by WFOs, as well as other federal, state, and local government agencies.

Fuels

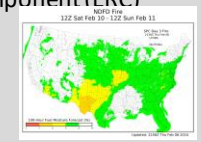
1. Assess Fuel Status



Energy Release Component (ERC)

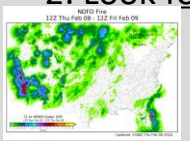


Burning Index (BI)

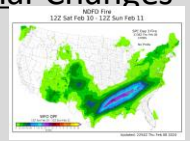


Fuel Moisture

2. Look for Potential Changes



Recent Precip



Forecast Precip

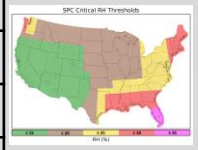
3. Are there Fuels Present to Burn?

Wildfire Hazard Potential

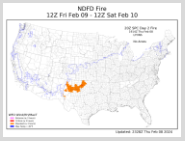
Weather

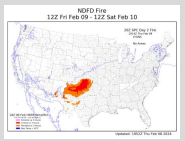
1. Wind/Relative Humidity Criteria

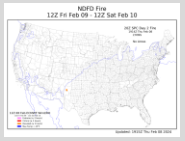
SPC Risk Category	Sustained Wind Threshold (mph)	RH Threshold
Elevated	15-20 (or 20+ < 3 hrs)	5% More Than Regional Threshold
Critical	20-30 (or 30+ < 3 hrs)	See Regional Thresholds Map
Extremely Critical	30+	2/3rds of Regional Threshold



2. Forecast







3. Dry Thunderstorms

Minimum criteria to consider for Critical risk from Dry Thunderstorms:

1. ≥ 40% coverage of cloud-to-ground lightning strikes with rainfall accumulation ≤ 0.10".
2. RH AOB regional thresholds; refer to regional low RH criteria graphic.
3. Temperatures ≥ 60° F (50° F) in the warm (cool) season.
4. GACC fuel dryness levels of dry, very dry, or high risk. In the absence of GACC outlooks, NFDRS Fire Danger Class of 3, 4, 5 and 100/1000-hr fuels ≤ 10% in the West or 10-hr fuels ≤ 10% in the East, and/or severe to exceptional long-term drought.

Other Factors

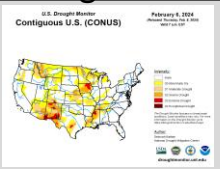
1. WFO Hazard Products

2. GACC Forecasts

3. IMET

4. Ongoing Fires

5. Drought Monitor



Outline of Research Topics

Lightning density prediction	Predicting Probabilistic Lightning Flash Density from the HREF Calibrated Thunder Guidance, *David Harrison (CIWRO/SPC)*
Fire occurrence prediction	Exploring the Role of Weather Forecasts in Predicting Wildfire Occurrence for CONUS Using the Unet3+ Deep Learning Model, *Bethany Earnest (CIWRO/SPC)*
Resource planning	SPC fire weather outlooks and associated observed fire behavior and deployed mitigation resources, *David Jahn (CIWRO/SPC)*

Predicting Probabilistic Lightning Flash Density from the HREF Calibrated Thunder Guidance

David Harrison[1,2], Patrick Marsh[2], Israel L. Jirak[2]

[1]Cooperative Institute for Severe and High-Impact Weather Research and Operations/University of Oklahoma

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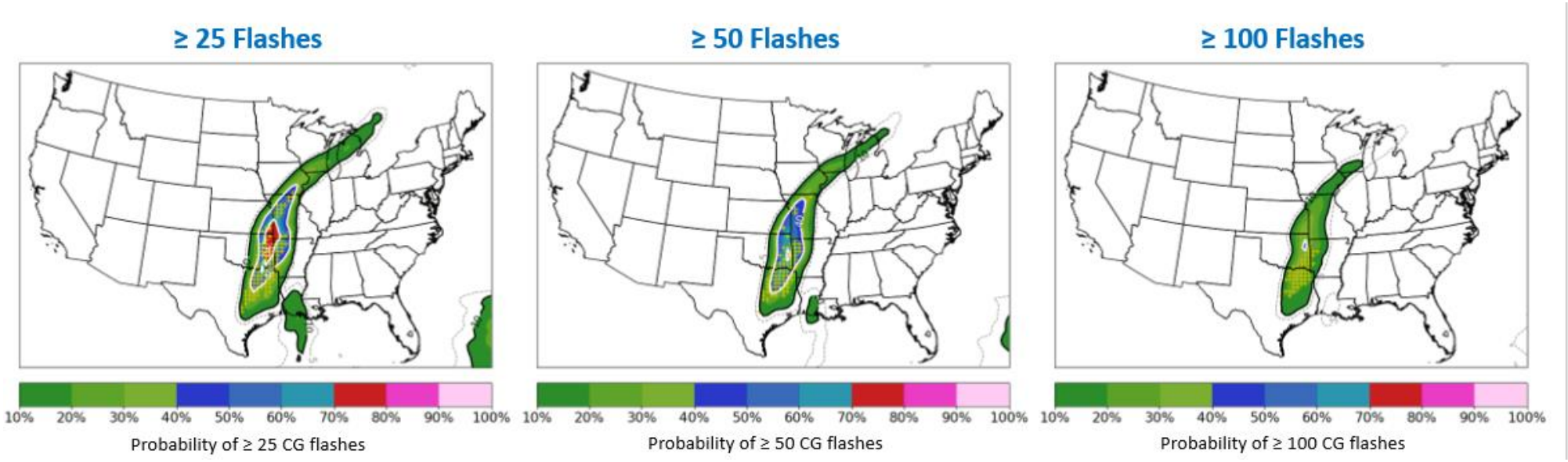
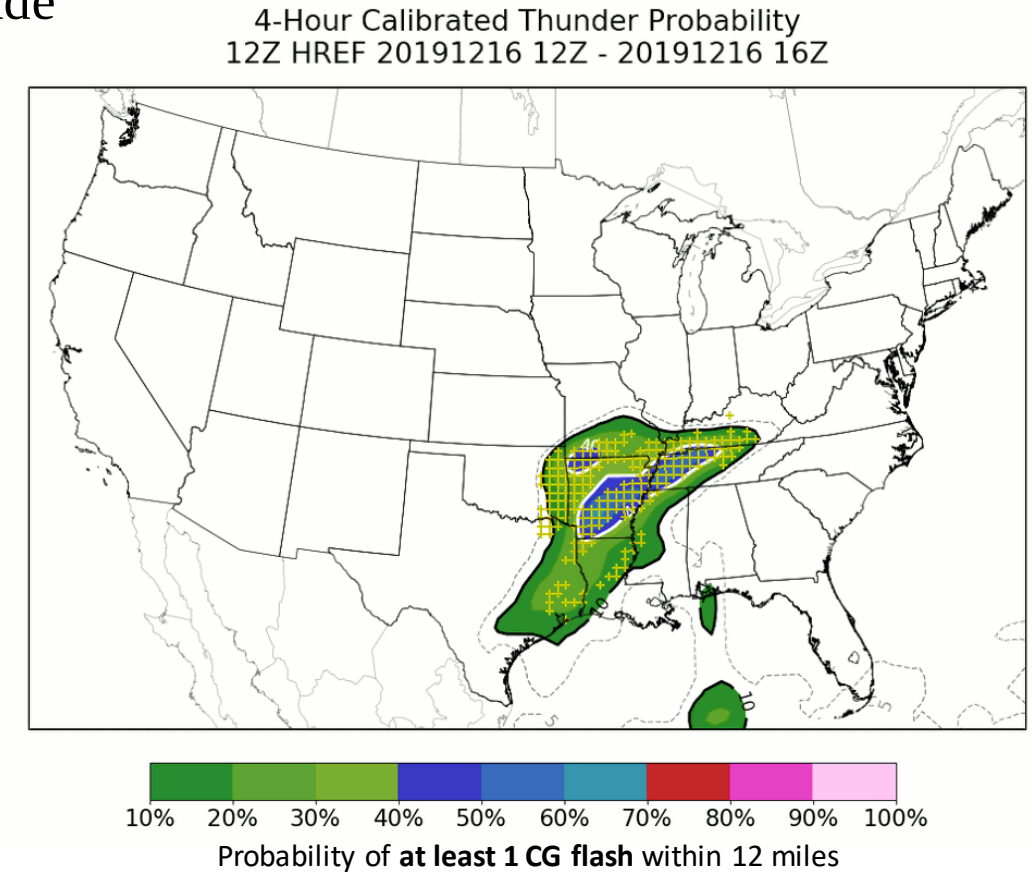


Lightning Flash Density Guidance – David Harrison

Lightning occurrence only

- The HREF Calibrated Thunder guidance (HREFCT) was made **operational within NWS in May 2021**
  - Uses prognostic HREF storm-scale attributes and environmental parameters to predict the probability of ≥ 1 CG flash
  - Z_{-10C}, Accumulated Precipitation, MU LI
  - Proven to be skillful and reliable at 1-, 4-, and 24-hour intervals
  - Widely used within SPC to help produce Thunderstorm Outlooks



Harrison, D. R., M. S. Elliott, I. L. Jirak, and P. T. Marsh, 2022: Utilizing the High-Resolution Ensemble Forecast System to produce calibrated probabilistic thunderstorm guidance. *Wea. Forecasting*, **37**, 1103–1115, https://doi.org/10.1175/WAF-D-22-0001.1.

https://www.spc.noaa.gov/exper/href/?model=href&product=guidance_thunder_hrefct_004h

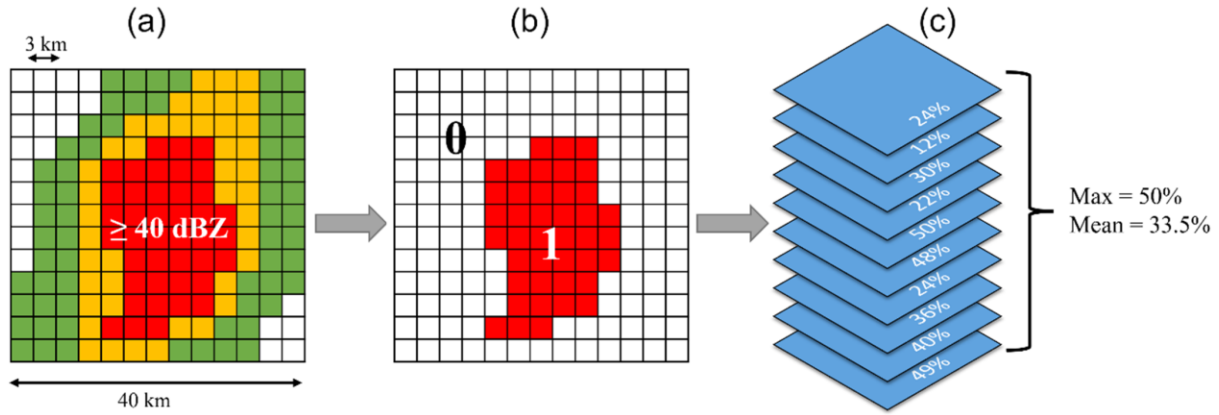
Lightning Flash Density Guidance – David Harrison

Lightning density probability

Labels: CG lightning flashes provided by Vaisala's NLDN

Input variables:

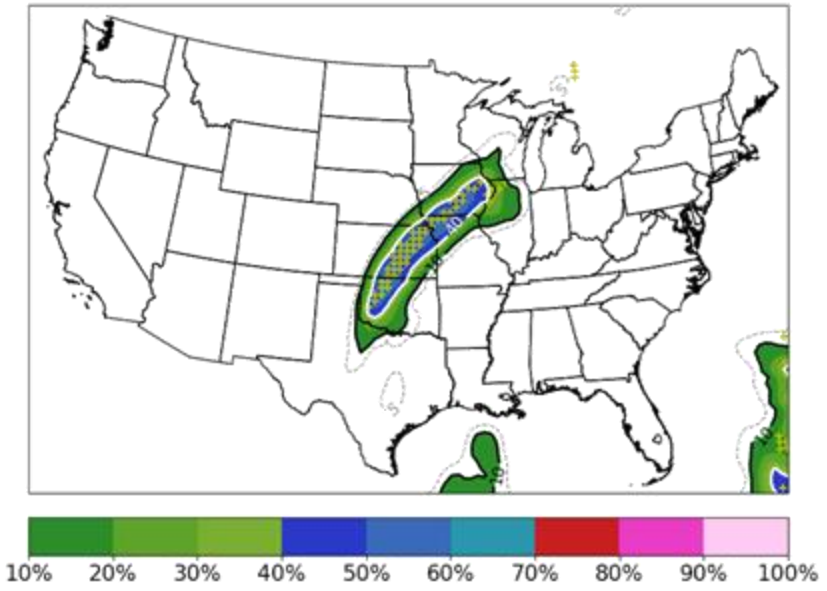
- HREF calibrated guidance 4-hour forecasts
  - operational system that predicts probability of lightning occurrence, but not density
  - Based on HREF storm and env. attributes, observed radar reflectivity and env. stability
- Neighborhood Maximum Updraft Vertical Velocity
- Ensemble Mean/Max Fractional Coverage $Z_{-10C} \geq 40\ dBZ$



$Z_{-10C} \geq 40\ dBZ$

20221104 4-hour Lightning Density Forecasts

12z HREF/HREFCT; F04 – F39

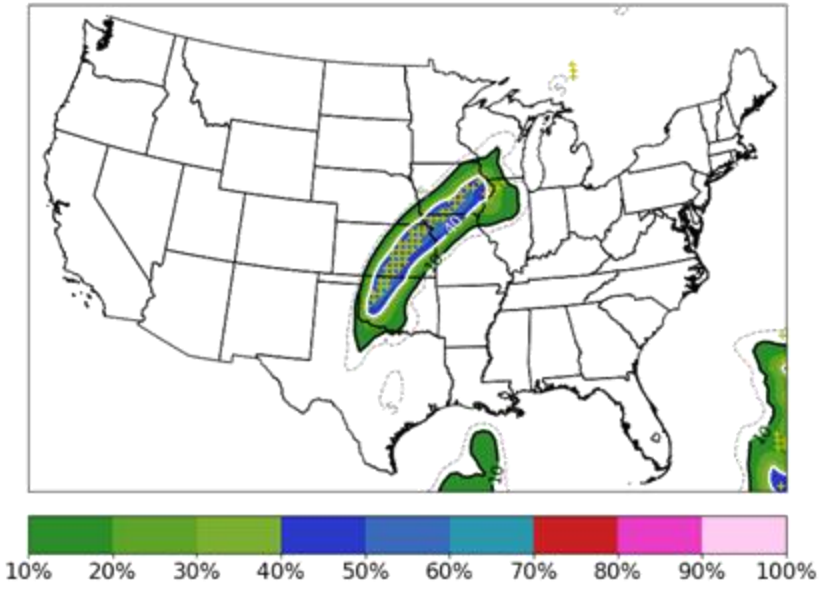


Probability of **> 25 CG flashes** within 12 miles

20221104 4-hour Lightning Density Forecasts

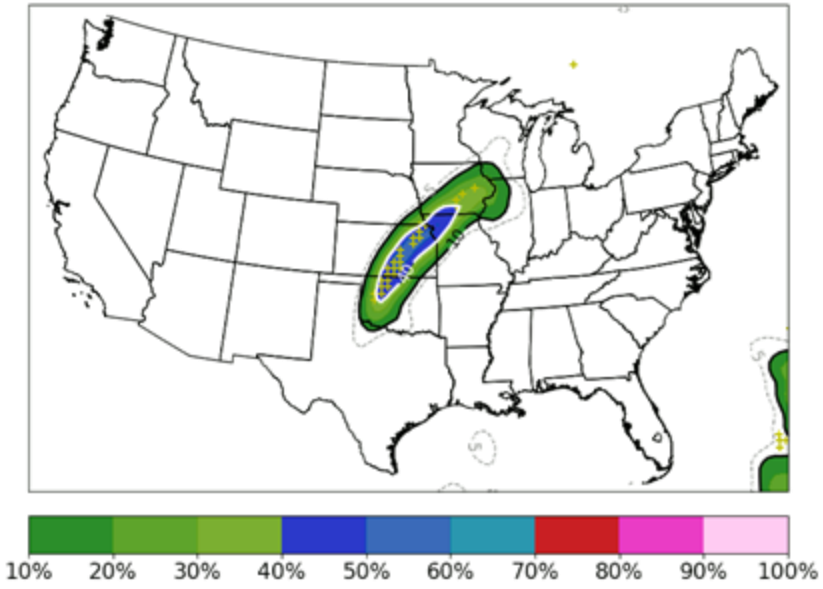
12z HREF/HREFCT; F04 – F39

≥ 25 Flashes



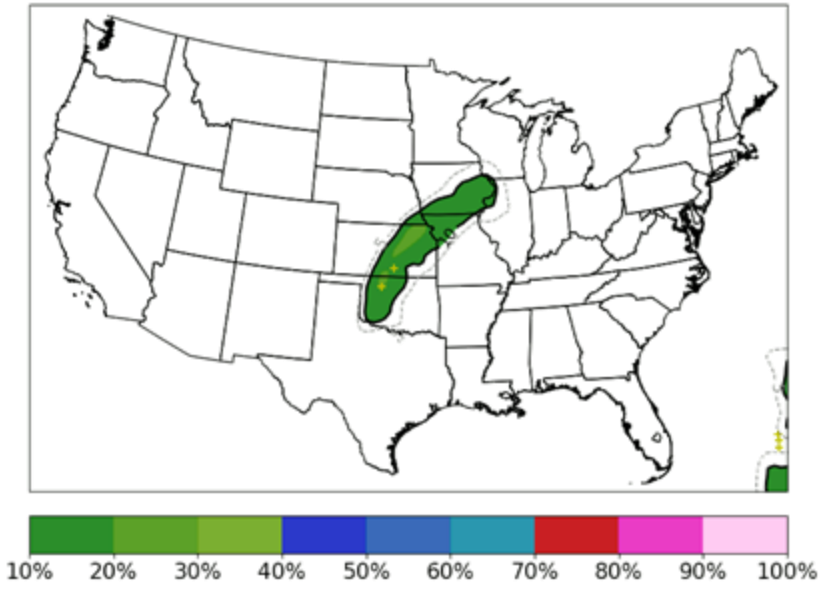
Probability of ≥ 25 CG flashes

≥ 50 Flashes



Probability of ≥ 50 CG flashes

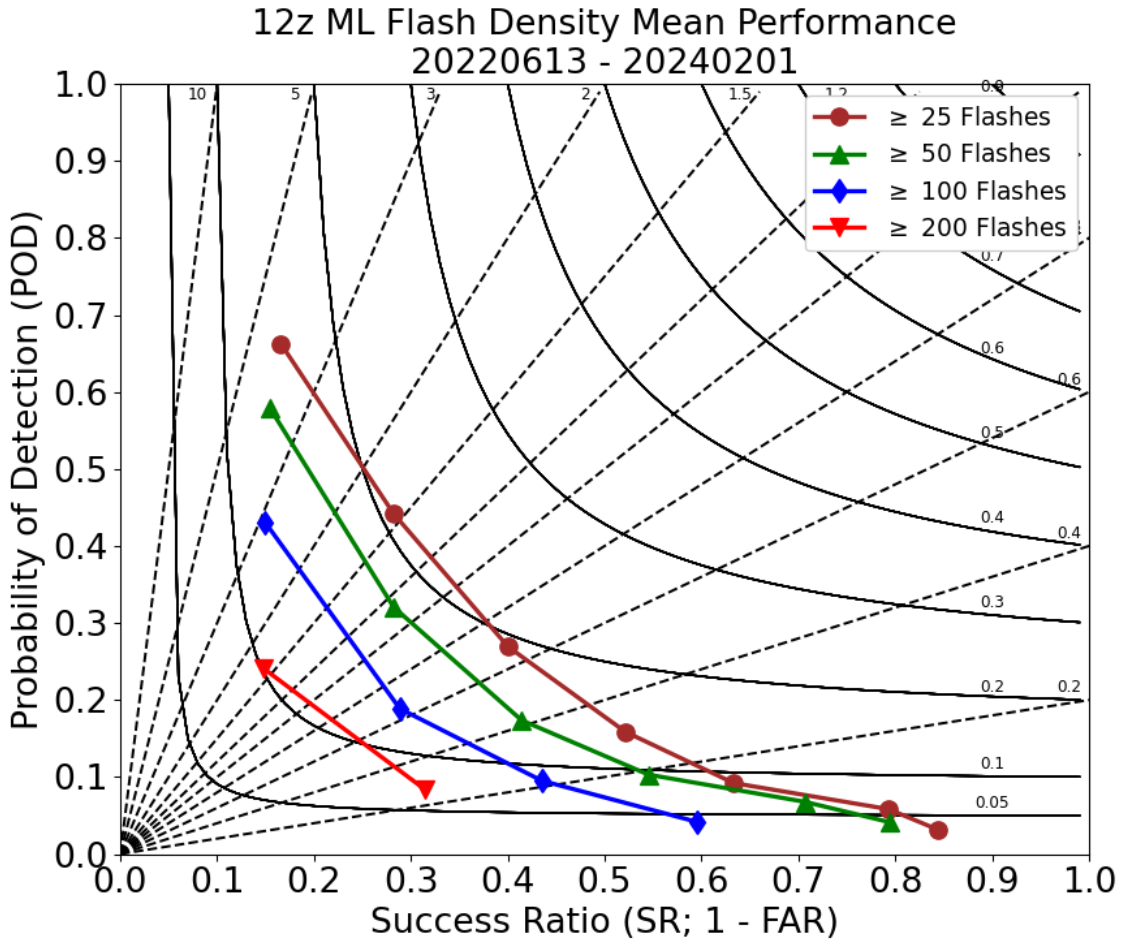
≥ 100 Flashes

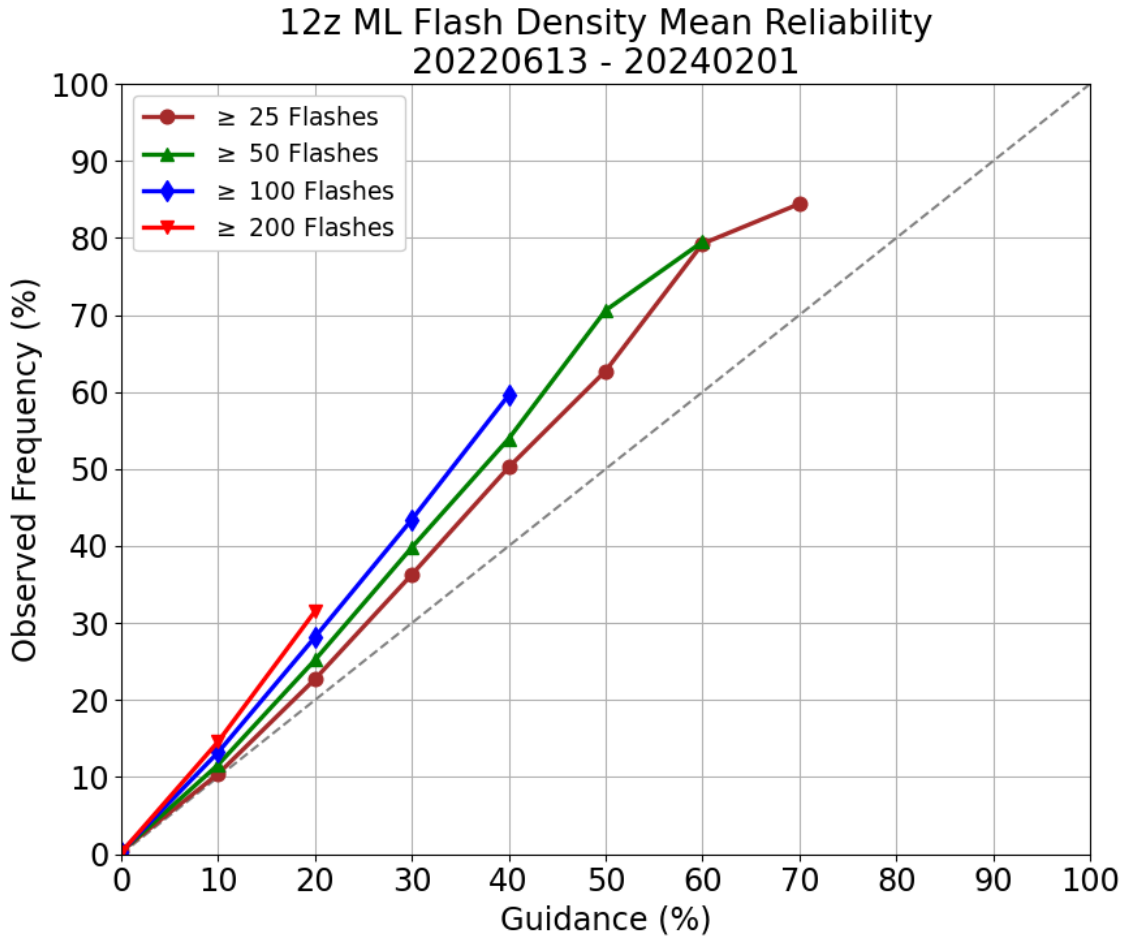


Probability of ≥ 100 CG flashes

Lightning Flash Density Guidance – David Harrison

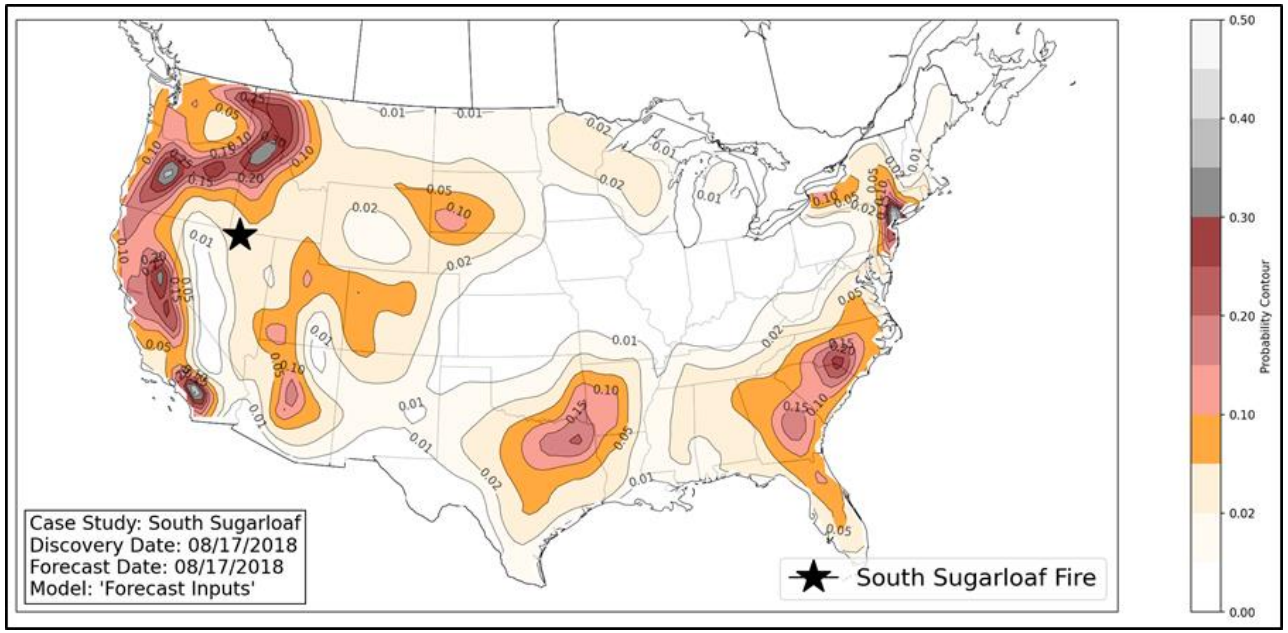
Skill





Exploring the Role of Weather Forecasts in Predicting Wildfire Occurrence Using the Unet3+ Deep Learning Model

Bethany Earnest[1,2], Amy McGovern[2], Chris Karstens[2]
[1]Cooperative Institute for Severe and High-Impact Weather Research and Operations/University of Oklahoma
[2]OU School of Computer Science
[3]Storm Prediction Center/National Weather Service/NOAA



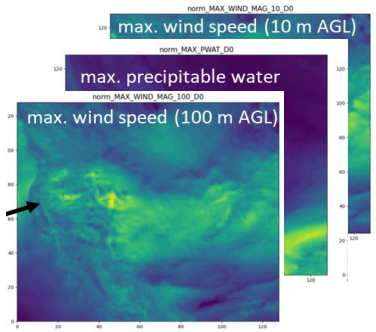
Example daily guidance product showing the probability of fire occurrence (generated separately for days 1-10)

Fire Occurrence Model – Beth Earnest

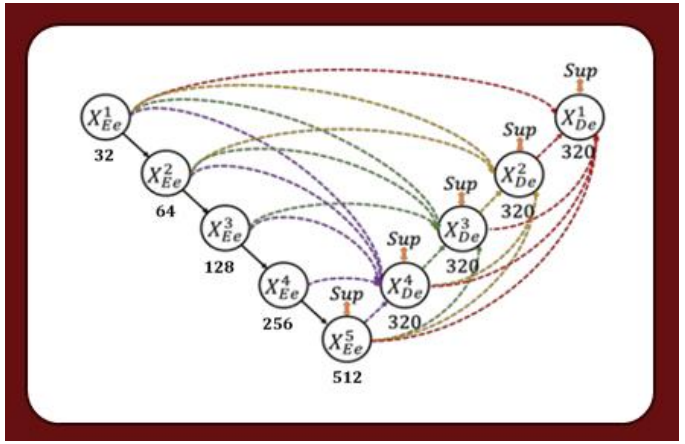
Model, Data Setup

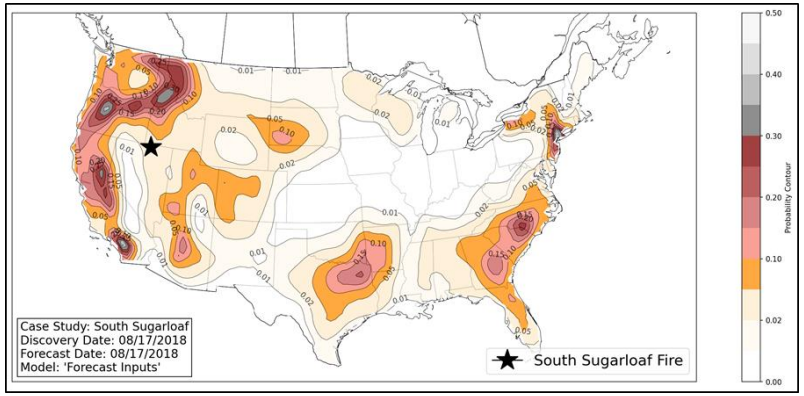
Predictors:

- GEFS reforecast fields
- temperature, winds, moisture
- 2000-2019



Machine Learning Model

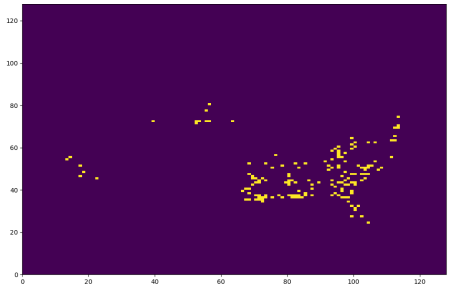




Fire occurrence guidance (days 0-10)

(11 models trained: one for each forecast day)

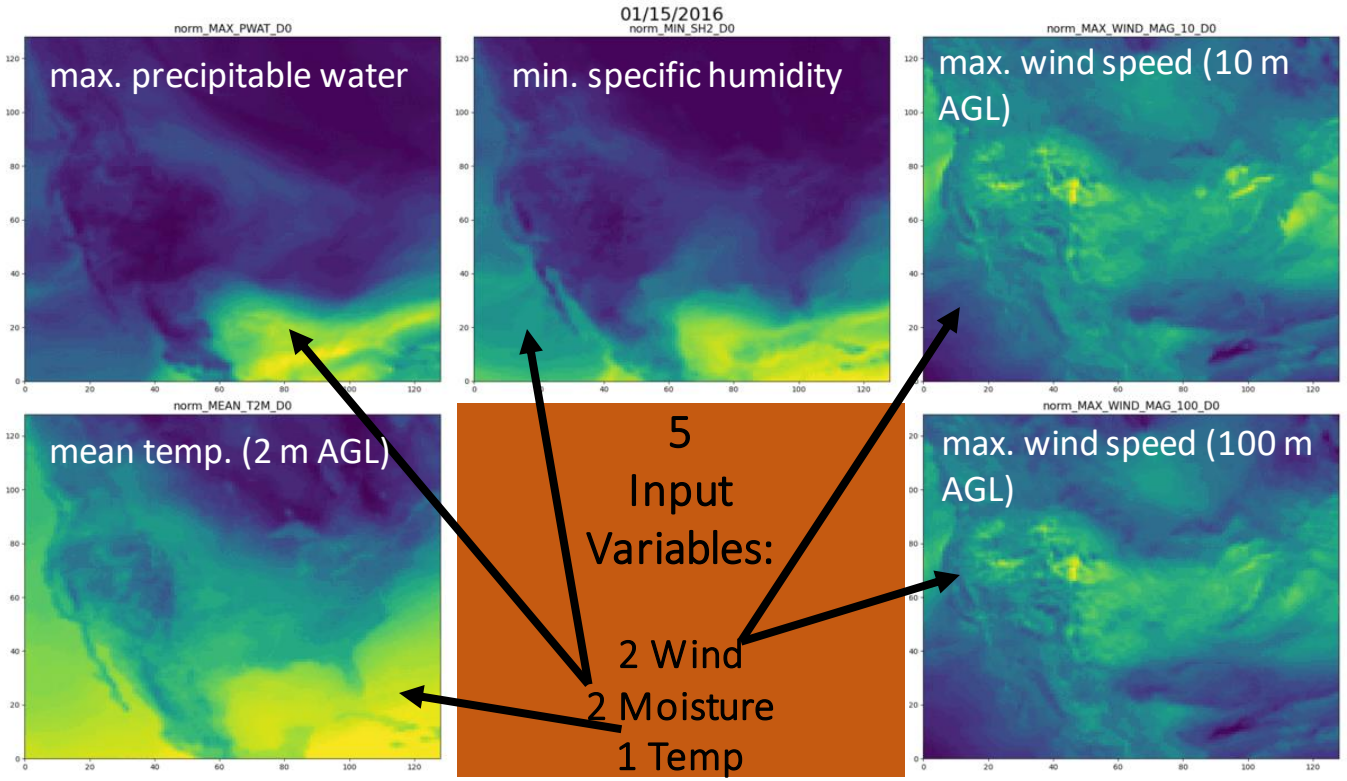
Labels: Fire occurrence data (2000-2019)

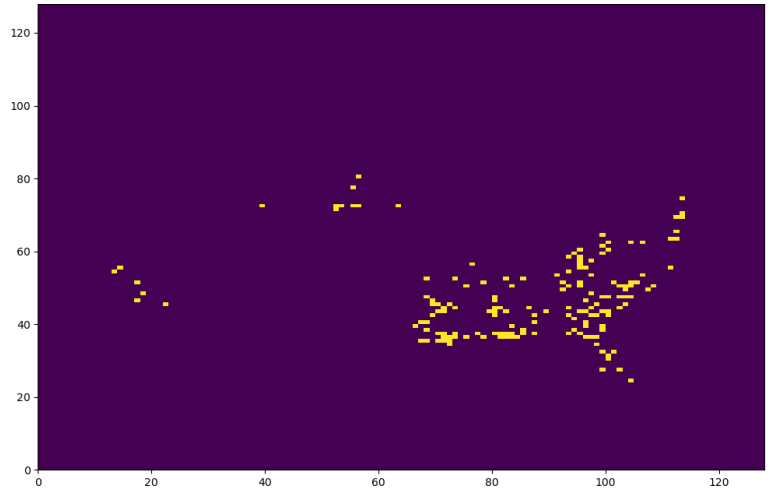


Fire Occurrence Model – Beth Earnest

Data Sources

Daily 40-km gridded GEFS reforecast fields (2000-2019)
24-hr. max/min/mean. field, normalized (0-1)



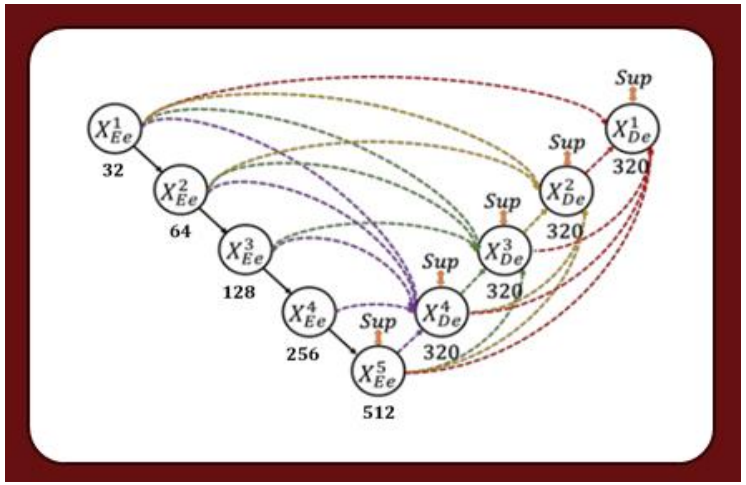


Wildfire data:

- FAP-FOD database (USDA Forest Service)
- All fires included (all sizes, all causes)
- Each point: at least one fire within 40 km grid cell within 24hr period

Fire Occurrence Model – Beth Earnest

Model Training



U-Net 3+ Model: Neural network w/ encoder-decoder architecture and full-scale skip connections

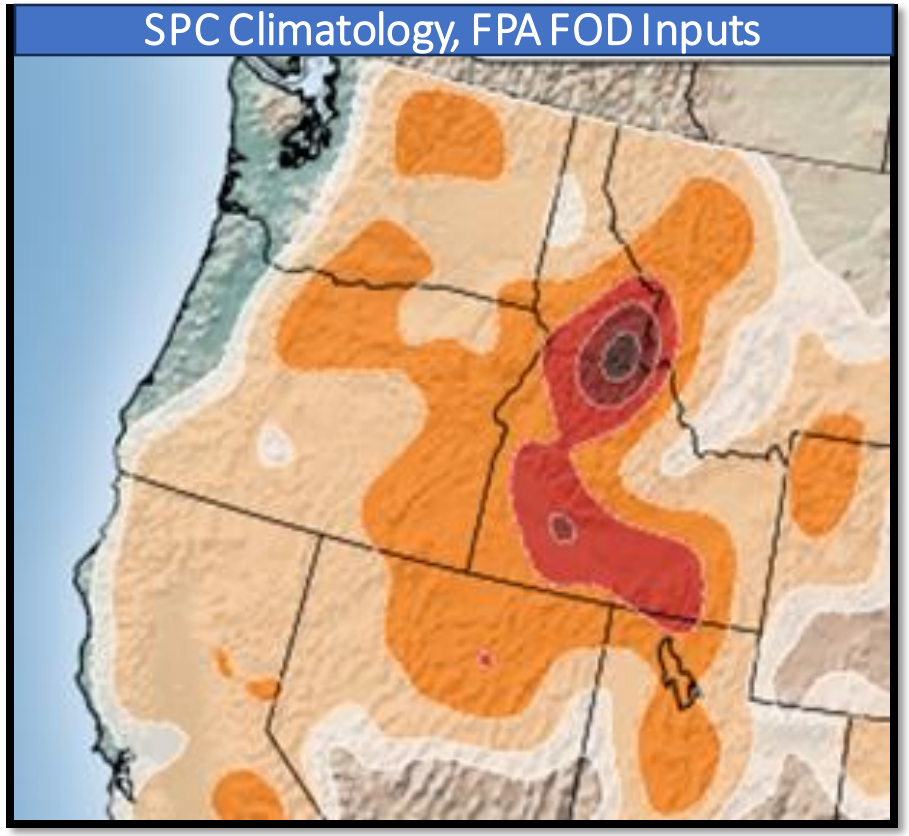
		Model: Observation Inputs	Model: Forecast Inputs
Day 0 Model	Day 0 Labels	Day 0 Observed Inputs	Day 0 Observed Inputs
Day 1 Model	Day 1 Labels	Day 0 Observed Inputs	Day 1 Forecast Inputs
Day 2 Model	Day 2 Labels	Day 0 Observed Inputs	Day 2 Forecast Inputs

Model trained separately for days 0-10, and separately using as inputs observations (day 0) OR GEFS forecast (of respective model forecast day, 0-10)

South Sugarloaf

Largest Lightning Fire of 2018

SPC Climatology, FPA FOD Inputs

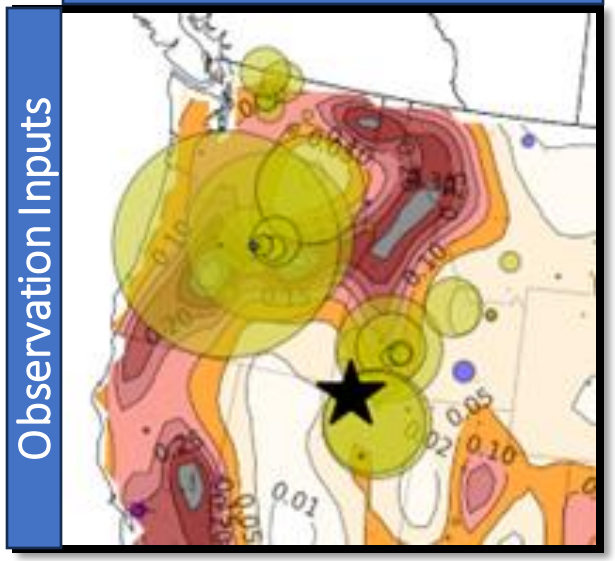


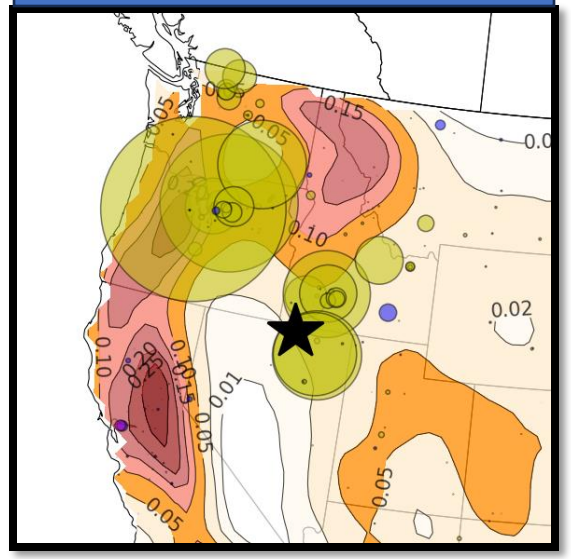
GEFS Inputs, FPA FOD Labels

DAY 0

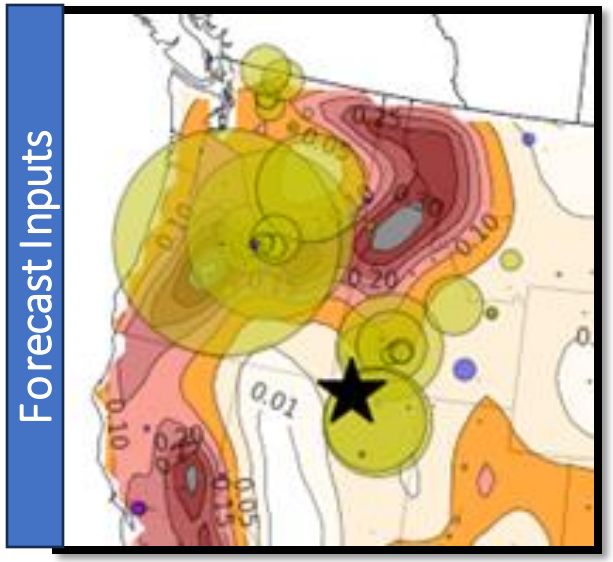
DAY 10

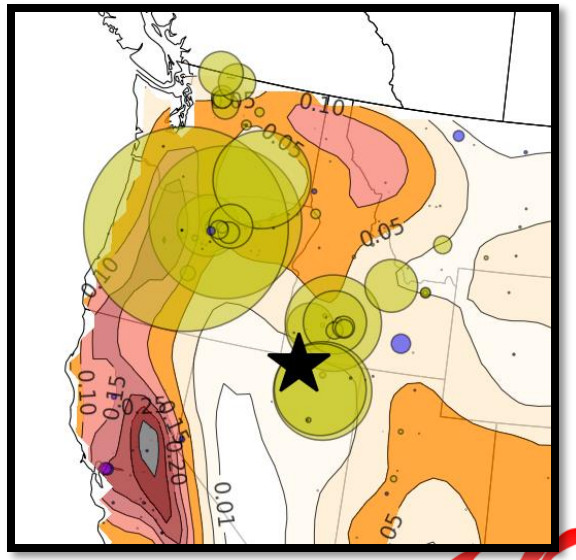
Observation Inputs





Forecast Inputs





Observed Fire Behavior and Deployed Mitigation Resources Related to Risk Categories of SPC Fire Weather Outlooks

David E. Jahn[1,2], Patrick Marsh[2], Israel L. Jirak[2]

[1]*Cooperative Institute for Severe and High-Impact Weather Research and Operations/University of Oklahoma*

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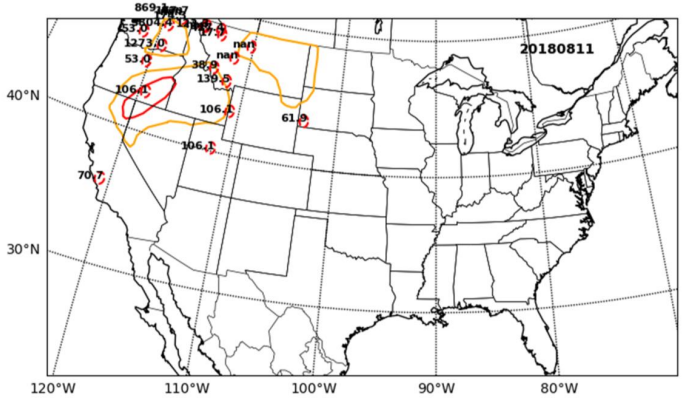
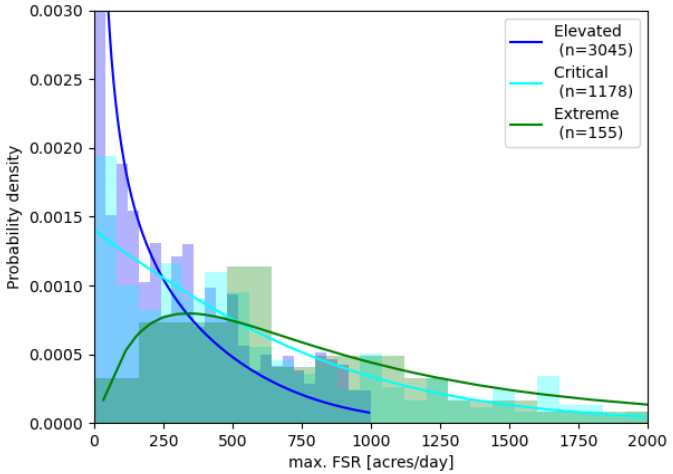
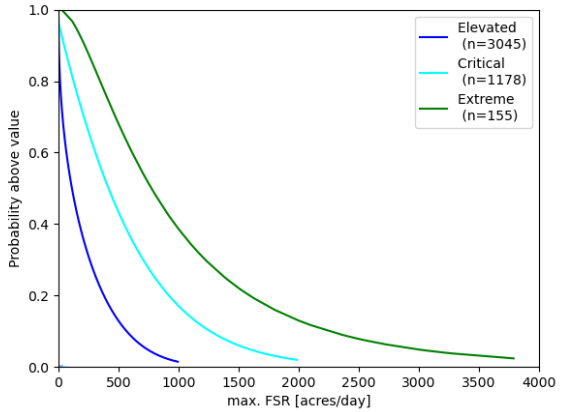


For an example case (2018-08-11), SPC Fire weather outlook critical level (yellow contour: 'elevated', red contour: 'critical'); dashed circles show wildfires with FSR [acres/day]



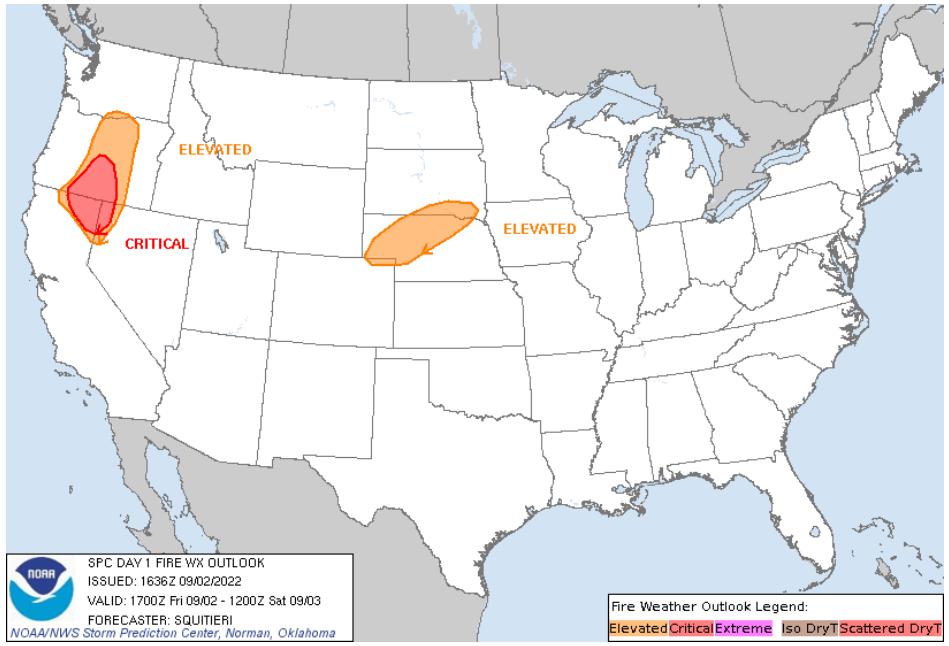


Fire Outlook and Resource Planning

Goal

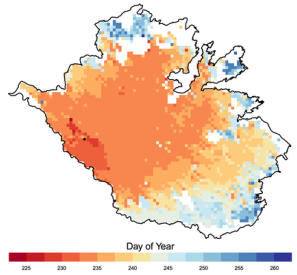
Goal: Identify a statistical relationship among risk categories of SPC fire weather outlooks and fire behavior as well as required suppression resources.

SPC Fire Weather Outlook



Guidance

Fire Spread



https://www.firelab.org/project/ics-209-plus

Cost $$$

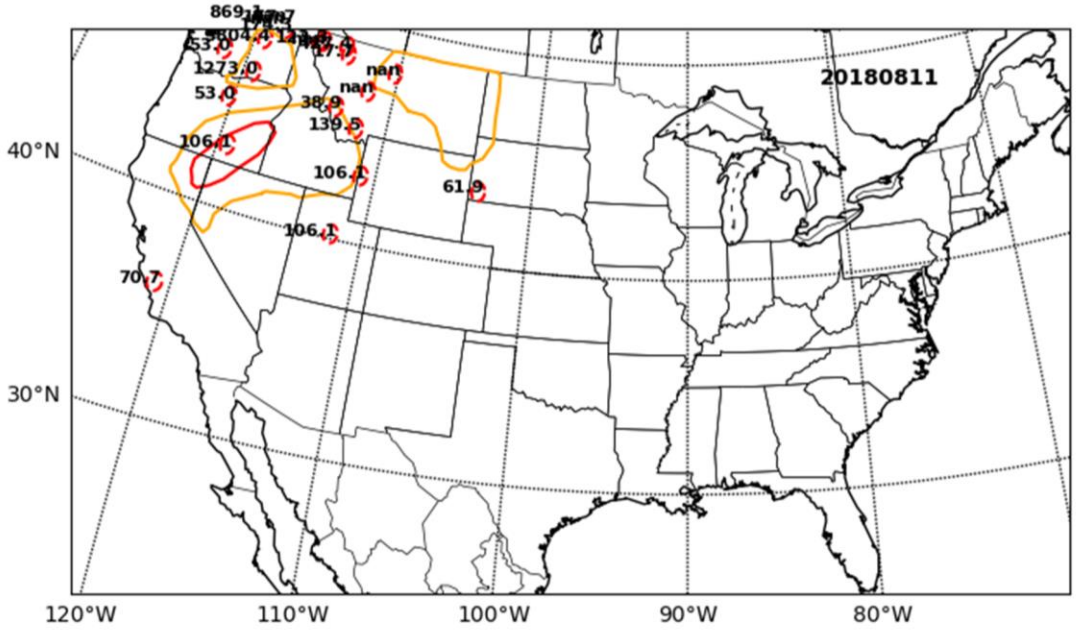
People

https://csfs.colostate.edu/wildfire-mitigation/becoming-a-wildland-firefighter/

Relate SPC outlook risk category data and wildfire data

ICS-209 Plus Data

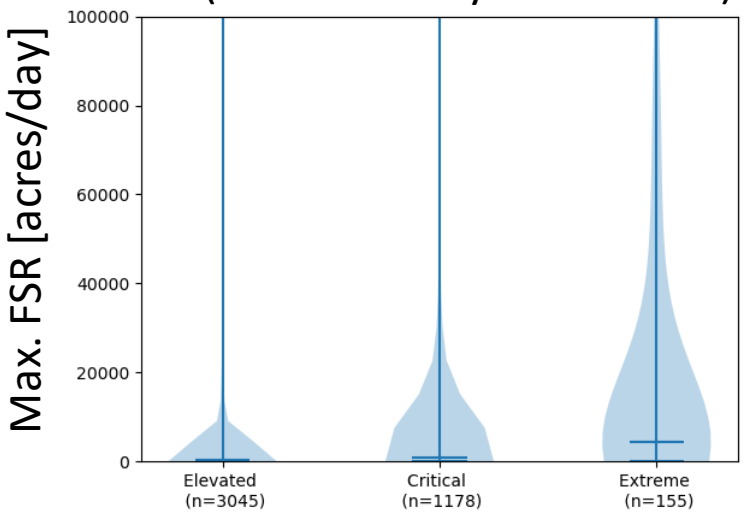
- Data for each wildfire: projected cost, fire spread rate, deployed personnel, … *(much more!)*
- 2% of all wildfires during 1999-2020 that represents 80% of suppression costs.
- https://doi.org/10.6084/m9.figshare.19858927.v3
- St. Denis, Lise A.; Short, Karen C.; McConnell, Kathryn; Cook, Maxwell C.; Mietkiewicz, Nathan P.; Buckland, Mollie; Balch, Jennifer K. 2023. All-hazards dataset mined from the US National Incident Management System 1999-2020. *Scientific Data*. **10**: 112.



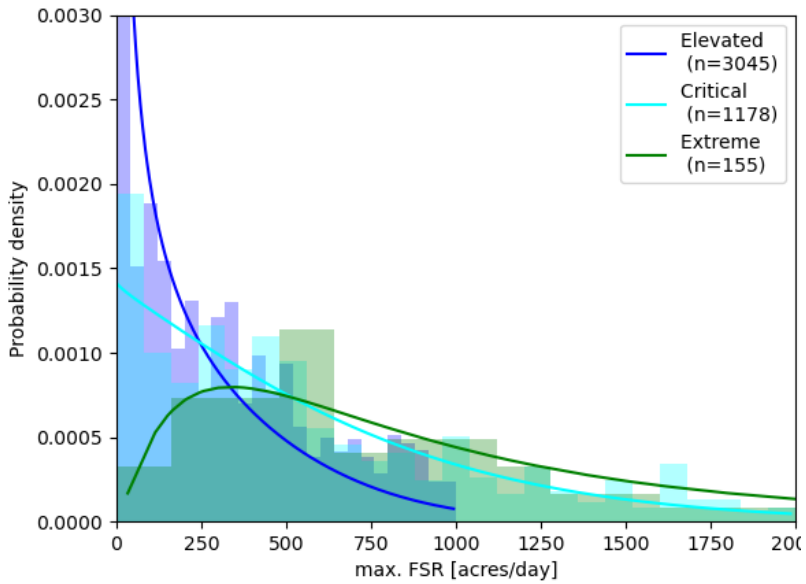
For an example case (2018-08-11), SPC Fire weather outlook critical level (yellow contour: 'elevated', red contour: 'critical'); dashed circles show wildfires with FSR [acres/day]

Probability of fire spread rate (FSR) related to fire risk category

Violin plots (Based on 15 years of data)

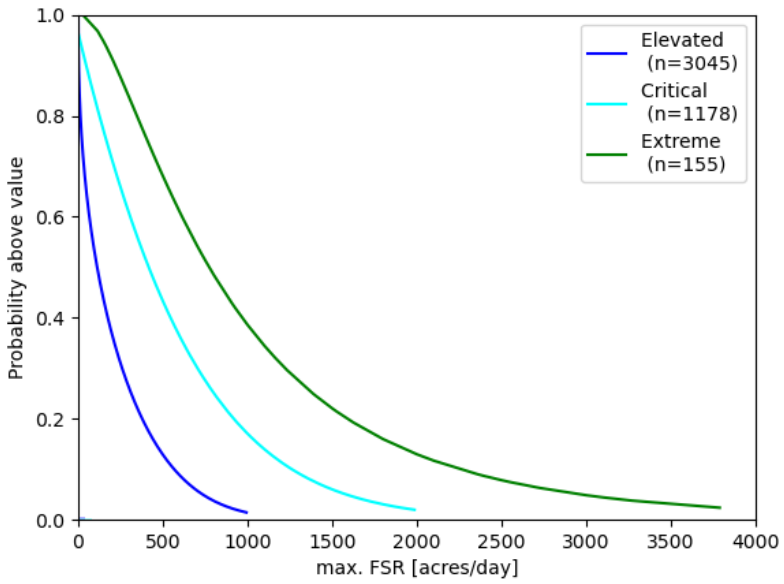


Probability density (Weibull fit)



Max. FSR [acres/day]

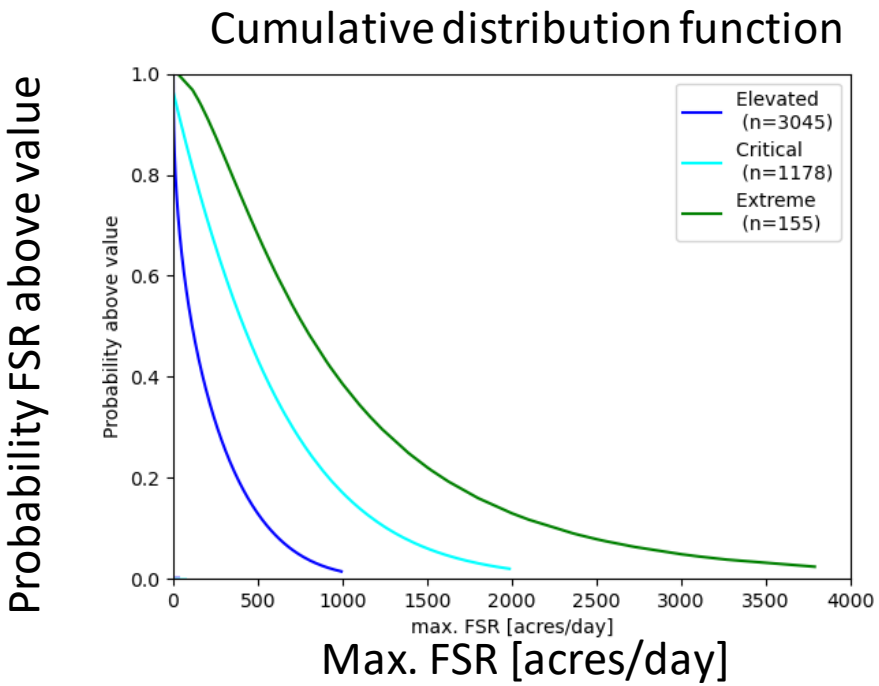
Cumulative distribution function



Max. FSR [acres/day]

Data Statistical Relationship

Probability of fire spread rate (FSR) related to fire risk category



	Elevated	Critical	Extreme
Prob. > 2000 [acres/day]	0%	1.9%	13.0%
Prob. > 1000 [acres/day]	0.1%	17.1%	38.6%
Prob. > 500 [acres/day]	12.9%	43.3%	68.1%

Extreme
Critical
Elevated

Posters

Fire Management and Risk Perception Through an Organizational Lens, *Evan Bentley, SPC*

Exploring the Role of Weather Forecasts in Predicting Wildfire Occurrence for CONUS Using the Unet3+ Deep Learning Model, *Bethany Earnest, CIWRO/SPC*

Predicting Probabilistic Lightning Flash Density from the HREF Calibrated Thunder Guidance, *David Harrison, CIWRO/SPC*

SPC fire weather outlooks and associated observed fire behavior and deployed mitigation resources, *David Jahn, CIWRO/SPC*