The Future of Fire

Extreme Disturbances and Climate Change: Threats to the Southeast

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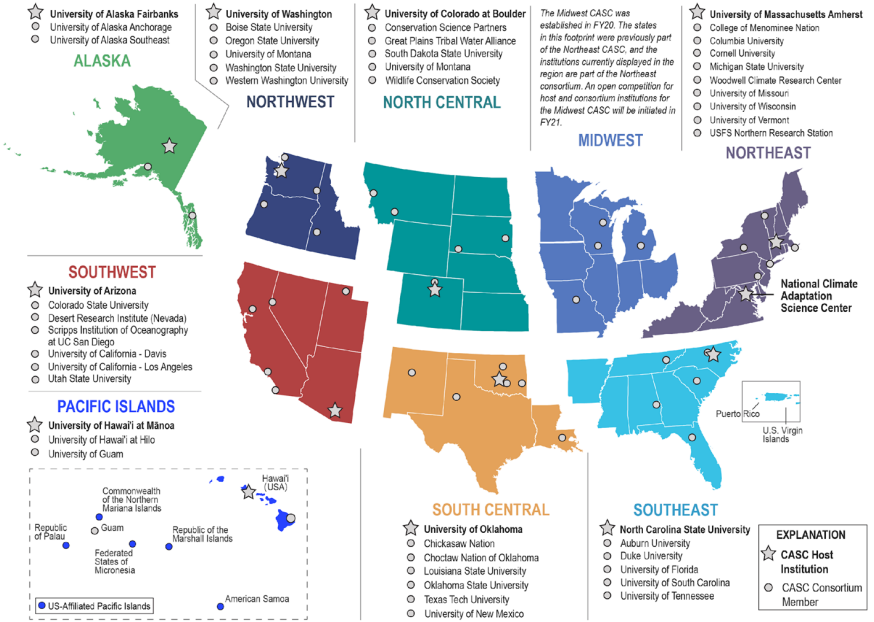
Reetam Majumder
Climate Adaptation Postdoctoral Fellow, SE CASC, NCSU

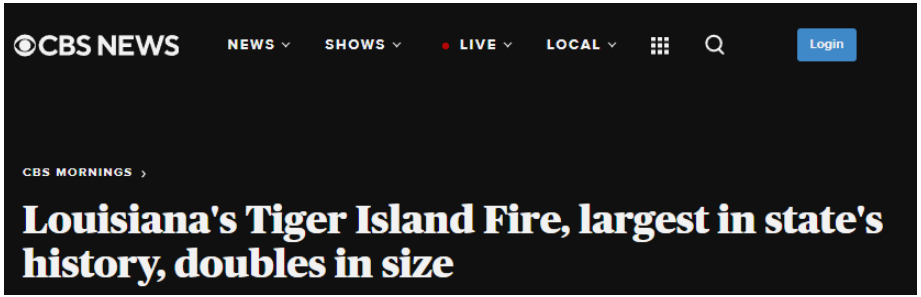
The Future of Fire

- NCASC funded postdoc cohort
- Individual regional projects
- National synthesis project
- SE CASC project - developing an early warning system for prescribed fire decision making
- Joint work with Adam Terando, Brian Reich, J. Kevin Hiers.



Acknowledgement: Southeast National Synthesis Wildfire and National Climate Adaptation Science Center (G21AC10045)

Louisiana wildfires, 2023



The Tiger Island Fire

- 441 wildfires in the state just in Aug
- The Tiger Island Fire burnt over 60,000 acres (94 sq miles); more than what usually burns in an entire season
- Caused by arson
- What were the underlying weather conditions?

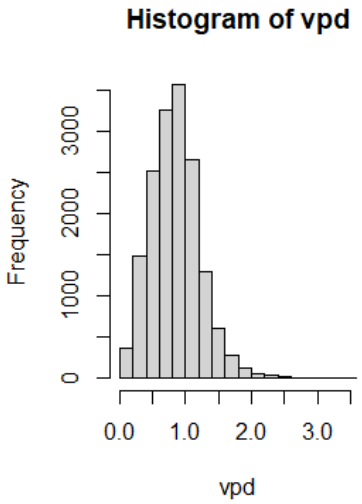
Outline

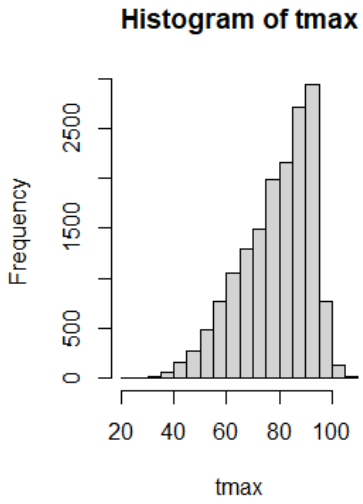
- The mathematics (statistics) of extremes (joint extremes)
- Prescribed burning and changing burn windows in the Southeast
- Decision making under changing climate
- Where do we go from here?

The mathematics of extremes

- Temperature and vapor pressure deficit are two indicators of a ‘potential to burn’ – aka hot and dry weather
- Consider daily tmax and vpd for Singer Town
- Daily data sourced from GridMet – Jan 1, 1979 to Sep 1, 2023

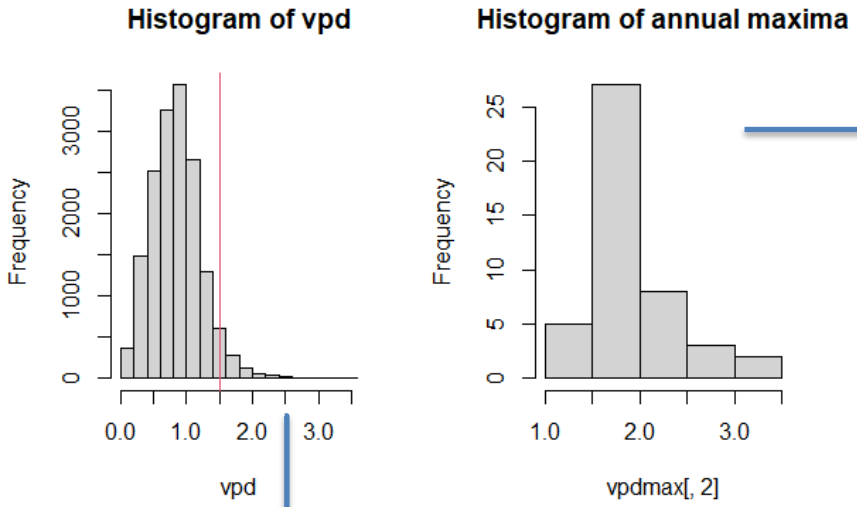
vpd and tmax for Singer





- Very different distributions
- Means aren't the best way to study them
- Upper tails are of particular interest
- How to study the tails?

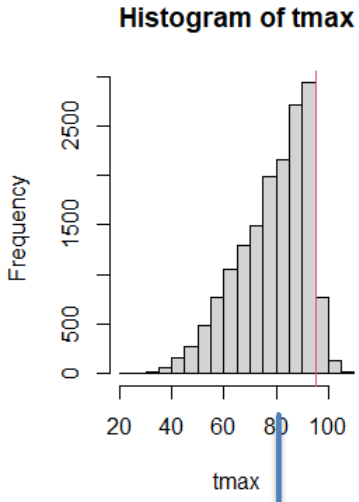
Studying tail behavior

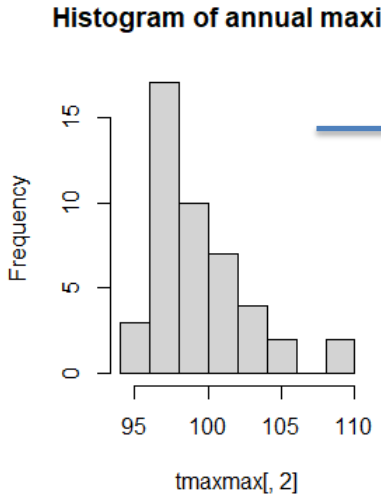


Block maxima: Take the maximum over a block of time, e.g., annual maxima.

Peaks over threshold: Choose large values above, e.g., the 95th percentile

Studying tail behavior



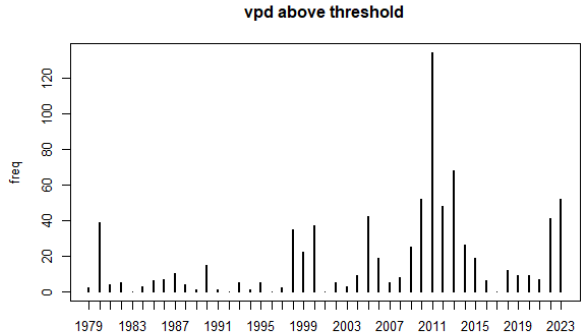


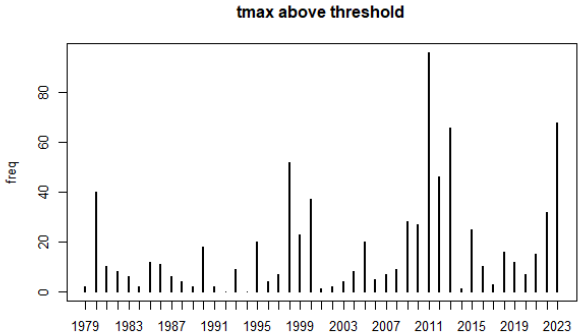
Modeled as a generalized extreme value (GEV) dist.

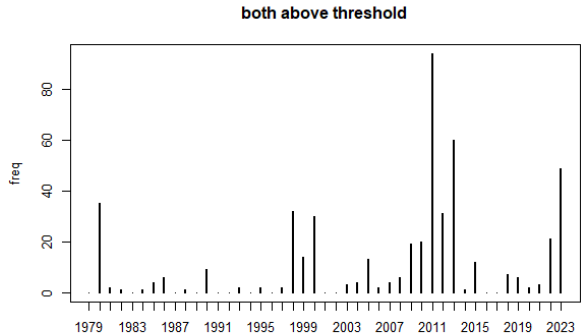
- **Block maxima**: max streamflow
- **POT**: aridity/temp
- Both GEV and GPD have a **tail parameter**

Modeled as a generalized Pareto (GP) dist.

Marginal behavior of vpd and tmax

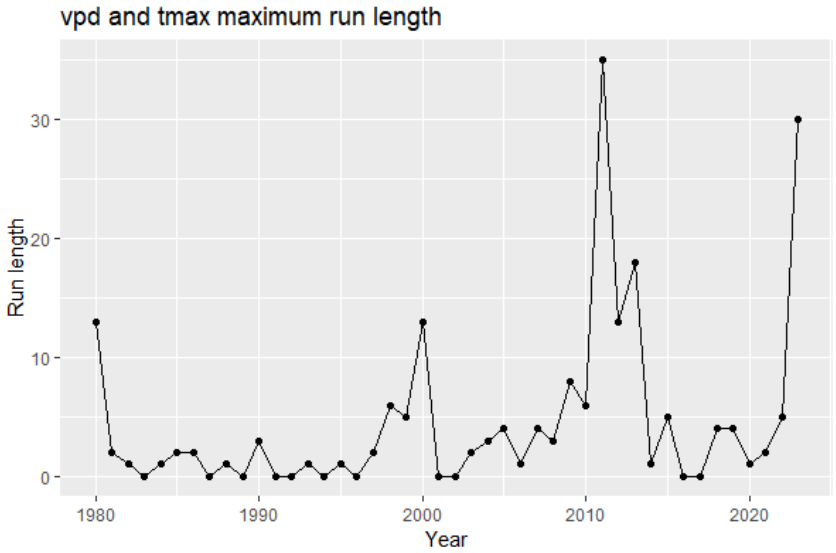






- Days above 95th percentile for each variable per year
- But just the *number of days* is maybe not the full picture

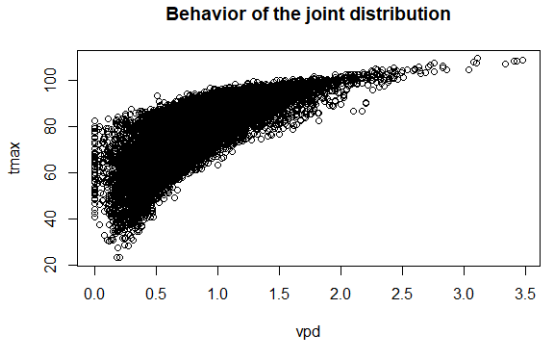
How long do these conditions persist

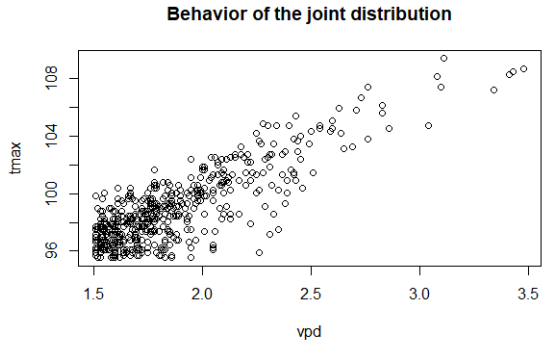


- Maximum # of consecutive days when both tmax and vpd were above their respective 95th percentile.
- Data until Sep 1, 2023
- Of course, does not account for incidence/ignition

Joint tail distribution of vpd and tmax

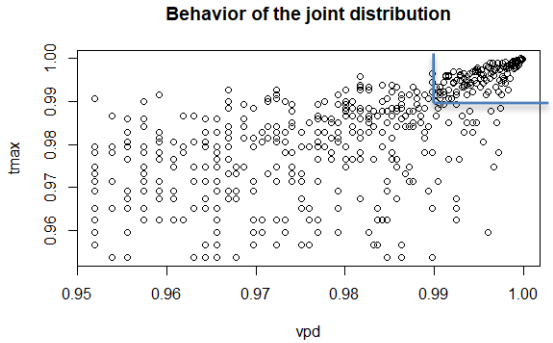
All data





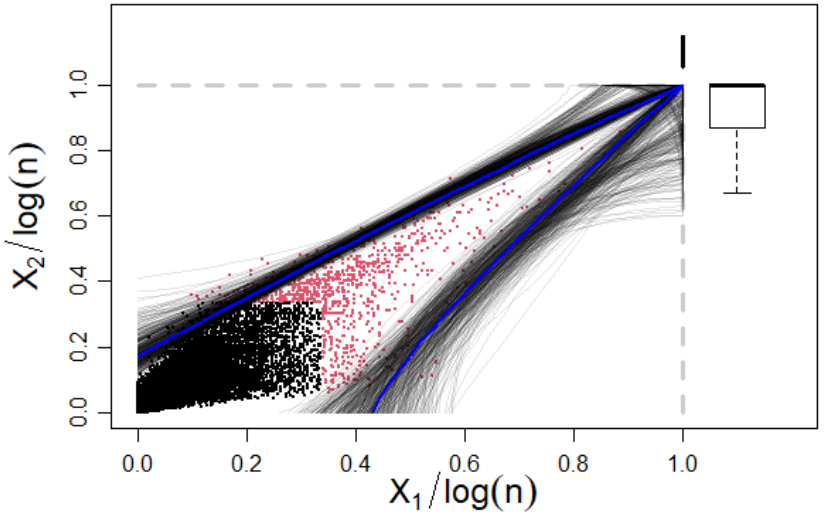
Above 95th %-ile

Ranked data



- Ranking (or fitting a GP distribution) *adjusts away* the effect of the marginals
- What is left is just their joint behavior
- Several approaches to study them

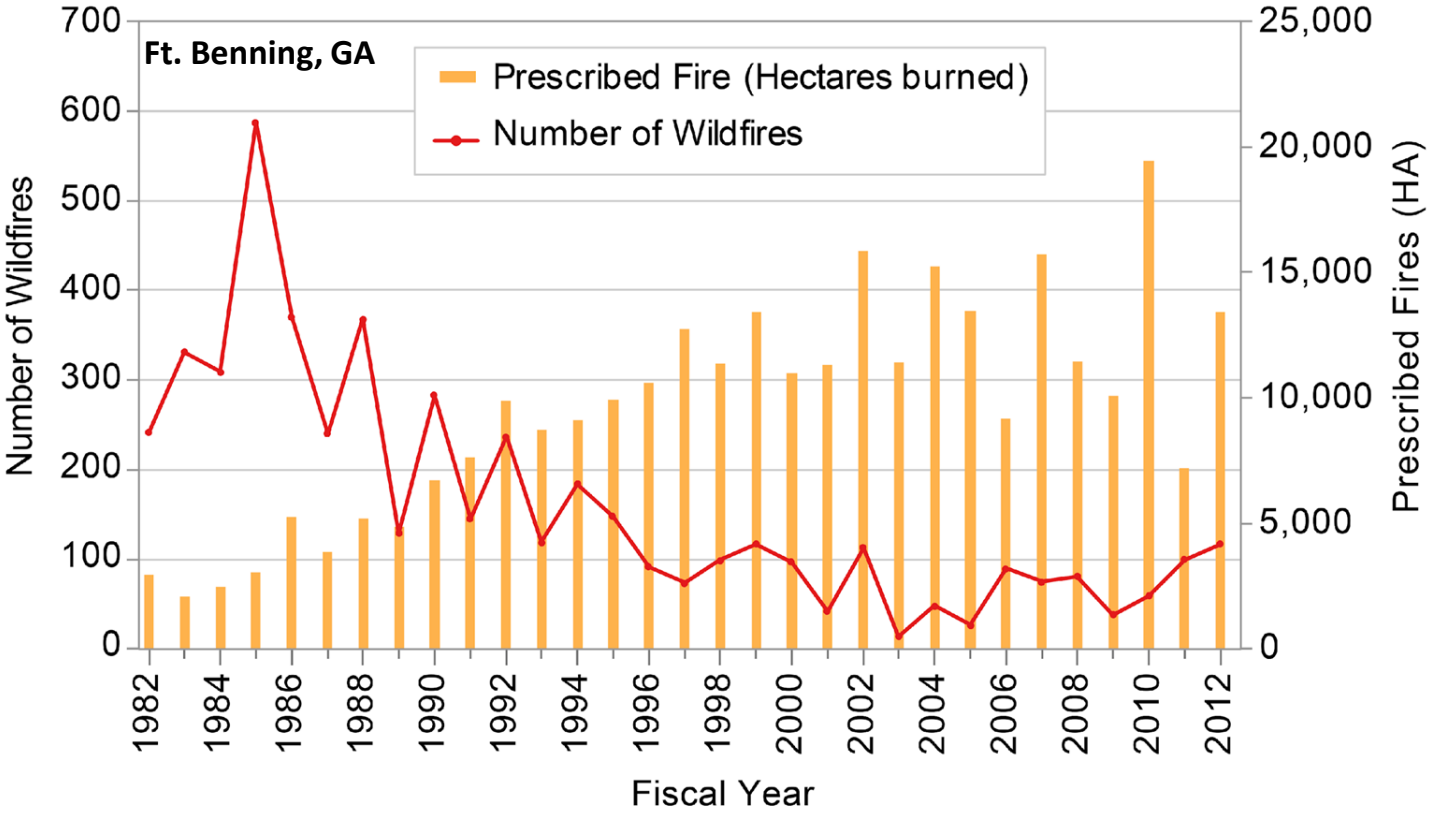
Joint tail behavior – geometric interpretation



- Bayesian analysis of the joint tail behavior
- The lines touching (1,1) indicates that even at extreme quantile levels, vpd and tmax will vary together
- Blue line is the median fit
- How does this affect us?

Prescribed burning in the Southeast

- Prescribed burning is a critical management tool in the Southeast
- More acres intentionally burned per year in SE than in any other region
- Two primary goals:
  - Habitat management
  - Wildfire risk reduction



Wildfire Risk Reduction

Figure 19.19 Carter et al. (2018)

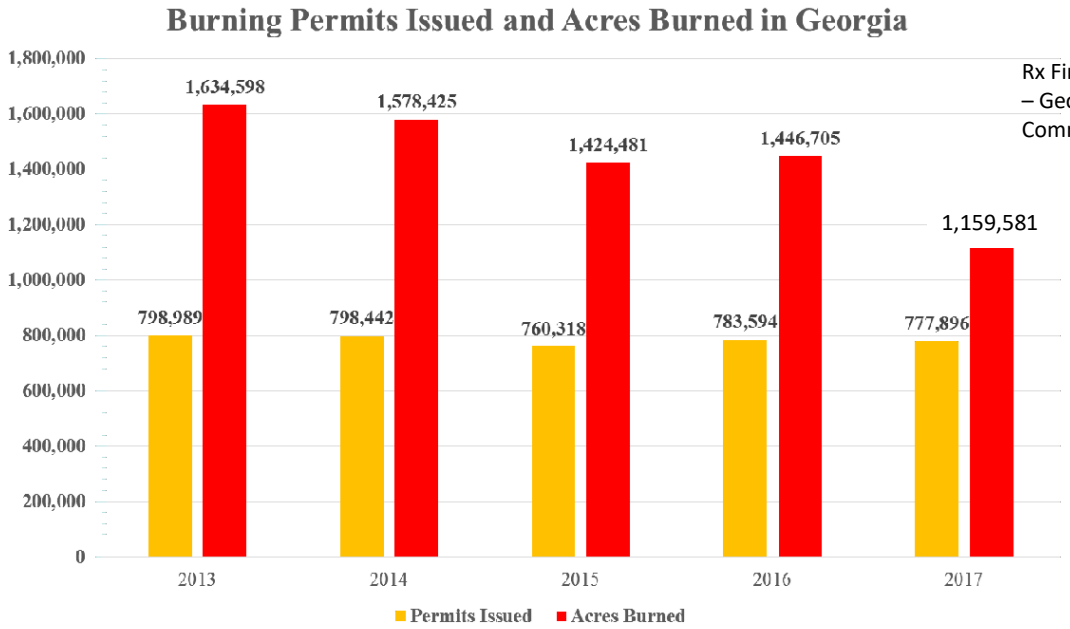
Prescription (Rx) parameters

- Suitable range of weather/fuel conditions (and other factors)
- **Common variables**: temperature, relative humidity, windspeed
- Temperature and humidity helps calculate fuel moisture
- Windspeed used to calculate both fire spread and smoke dispersion

Rx burn windows

- Temperature: 32-90 F
- Relative humidity: > 30%
- Wind speed: 2.25 – 8 m/s
- Rx burn managers need a certain period per year *within prescription* if they are to meet burn objectives
- Adverse conditions affect not only the burn, but also put Rx burn personnel at risk

Permitting and Acres Burned



Rx Fire Data: Chuck Williams – Georgia Forestry Commission

Fire Management is sensitive to climate variability and change

Changing burn windows

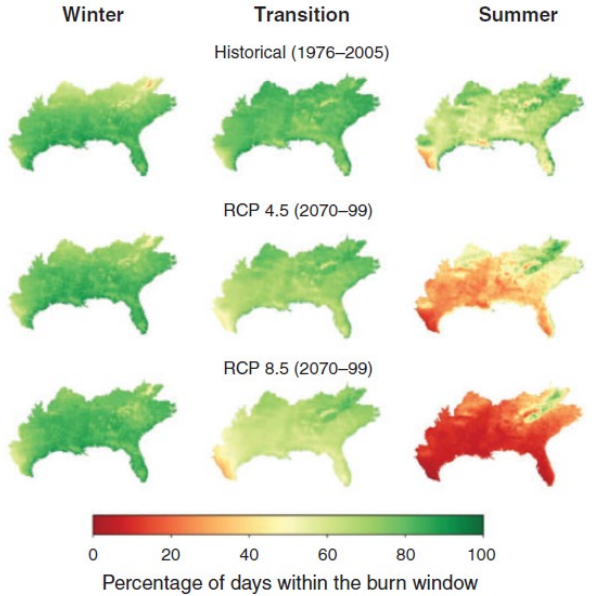


Fig. 4. Historical and projected percentage of days during winter (January and February), transitional (March, April, May), and summer (June and July) burn seasons that fall within accepted burn window conditions. Historical baseline period (1976–2005) and future conditions (2070–99) are averages calculated from 18 downscaled Global Climate Models under two future greenhouse gas emissions scenarios, RCP (Representative Concentration Pathway) 4.5 and 8.5.

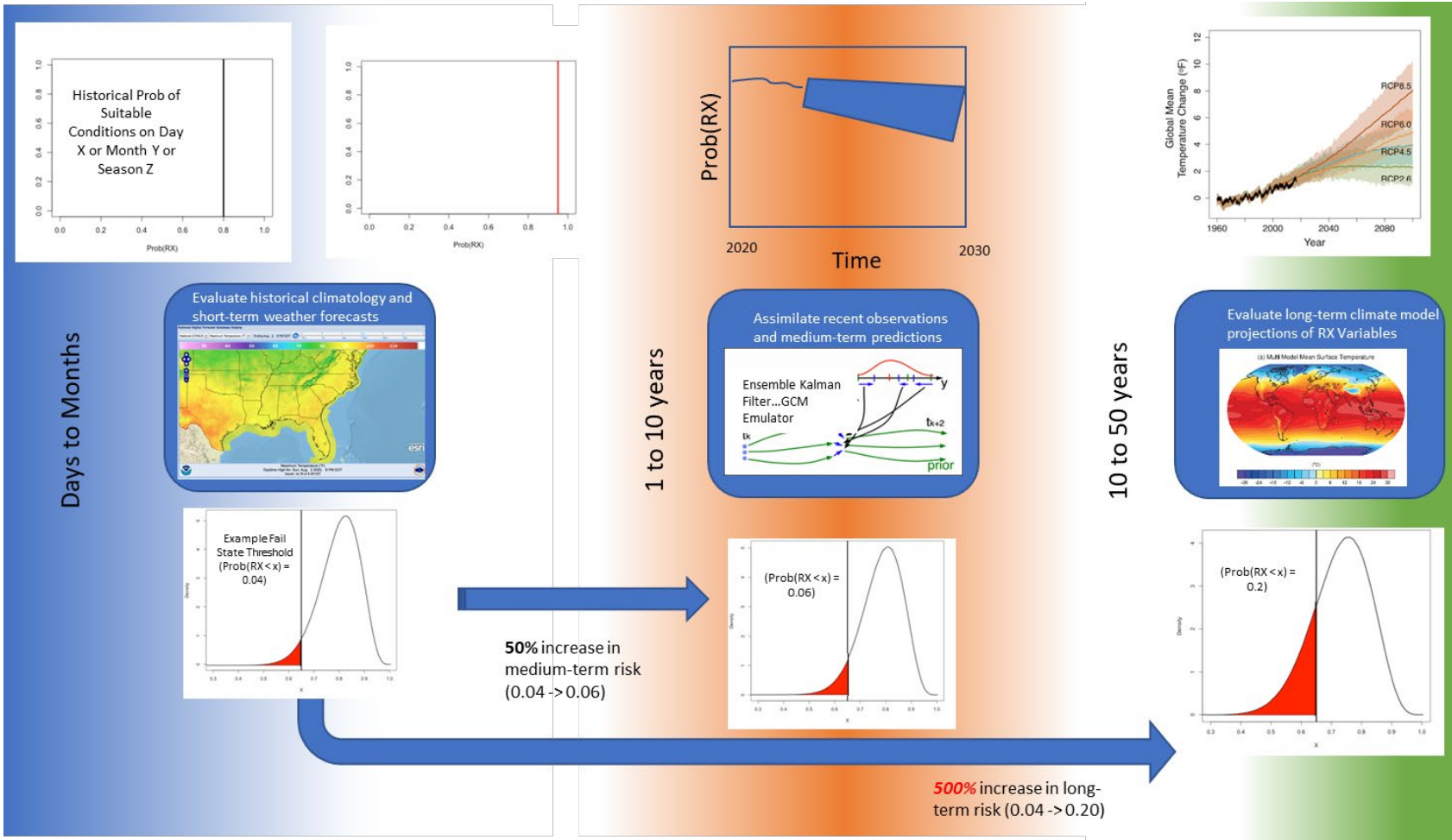
- Based on 18 GCMs from MACA
- The distribution of certain variables (e.g., noon time temps) have also shifted
- Overall shortening of burn windows

Image from Kupfer et al., International Journal of Wildland Fire (2020).

Decision making under changing climate

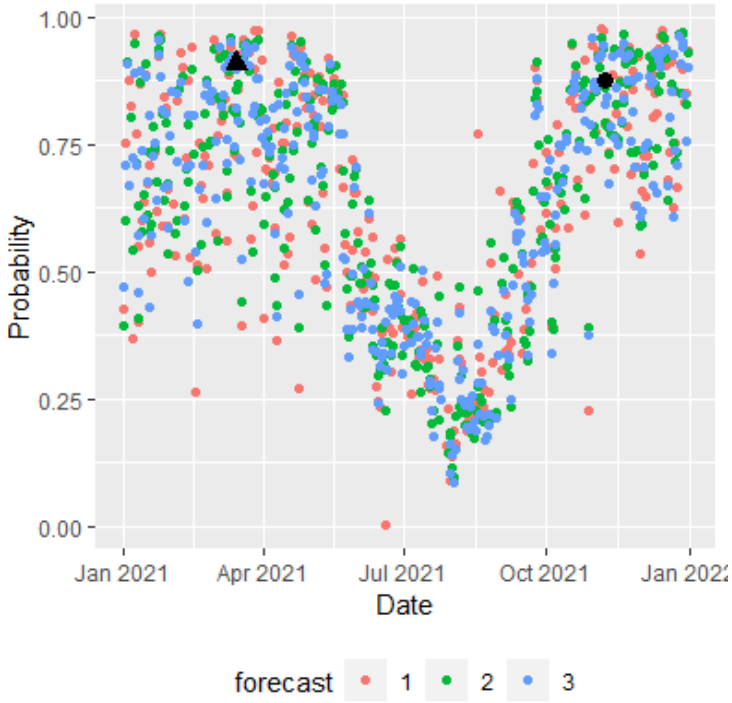
- Burn at different times of the day
  - Burn early/late since the ‘day’ window is shorter
- Burn at different times of the year
  - Multiple smaller burn seasons
- Relax the prescription parameters
  - Climate change progressing differently in different parts of the country
- Better allocation/logistics
  - Provide estimates (with uncertainties) of different areas being within prescription

Conceptual model of prototype Rx Early Warning System / Recommendation Engine



The Rx Fire recommendation engine

- Inputs
  - List of burn tracts with locations and area
  - Weather forecasts for the region
- Assess probability of fail-states
- Determine utility functions for burn decisions
- Outputs
  - Probability of staying within prescription + expected utility of Rx burns at locations
  - Ranked list of locations with highest expected utility

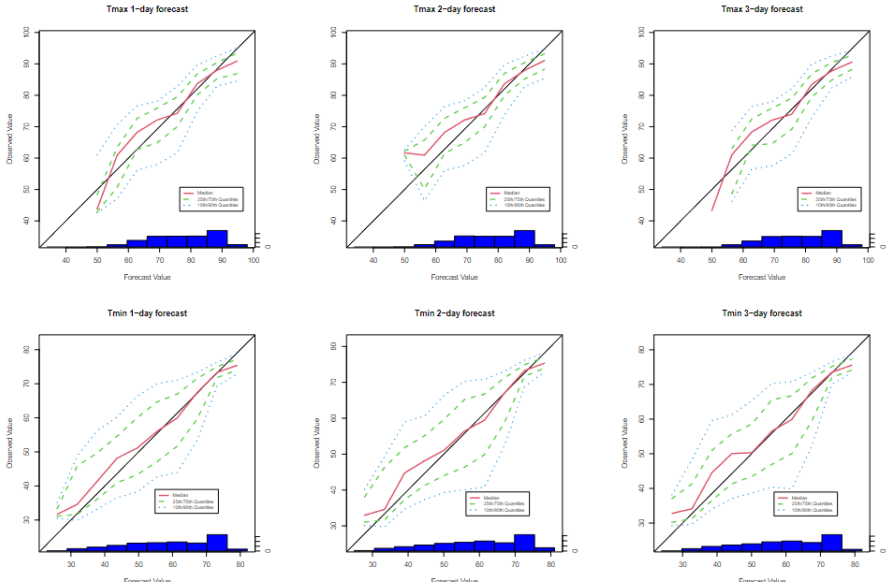


Eglin AFB Case study

- Detailed fire data available since the 1970s, including
  - Start and end dates
  - Shapefiles
  - Time since last burn
- 3-day weather forecast data from NDFD
- Observational weather data from GridMET
- Model fitted for 2015-2020, validation and burn allocations for 2021.

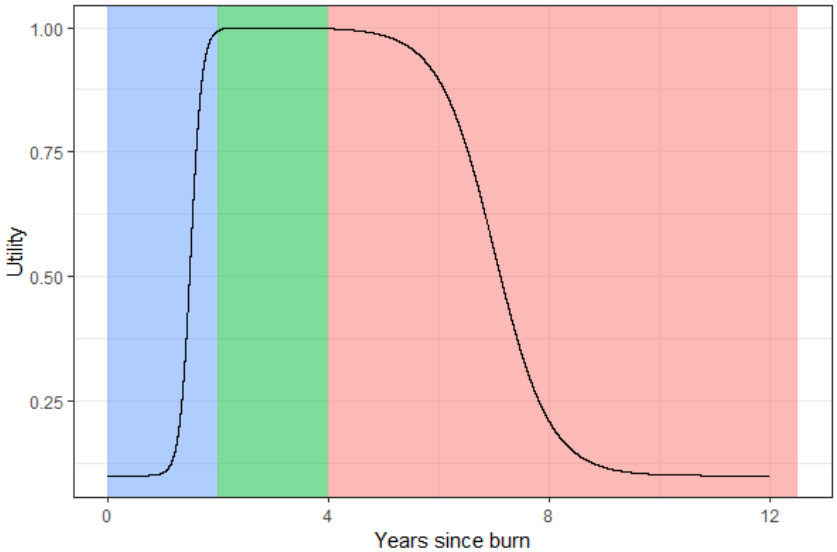
Probability of being within prescription

- Bayesian hierarchical model for joint forecast verification of prescription parameters
- In-built uncertainty quantification

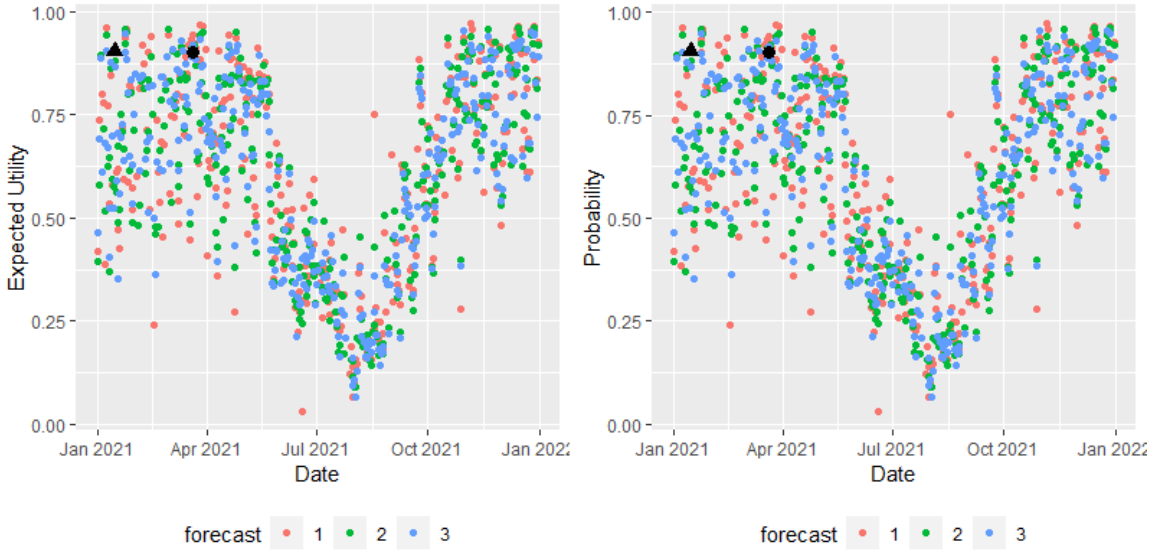


Utility function for time since burn

- Similar temporal utility functions can be constructed for days since rain
- Spatial utility functions of interest include area, distance to the wildland urban interface, distance to nearby tracts etc.

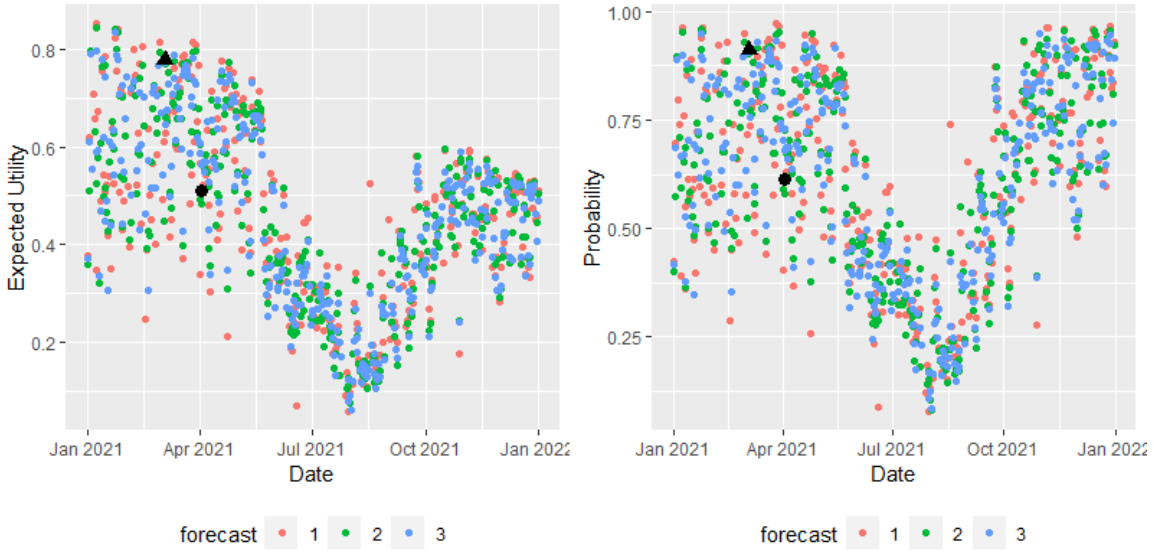


Burn allocation example 1



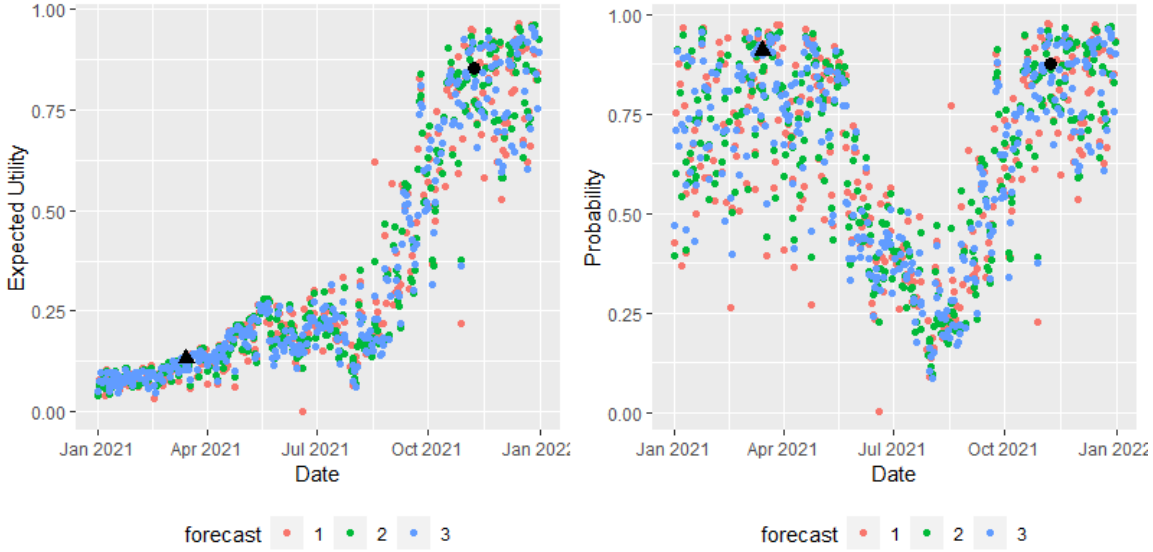
- Only burn if Prob(within threshold) > 90%, at most 2 plots/day
- 4 years since last burn for this location

Burn allocation example 2



- 7 years since last burn

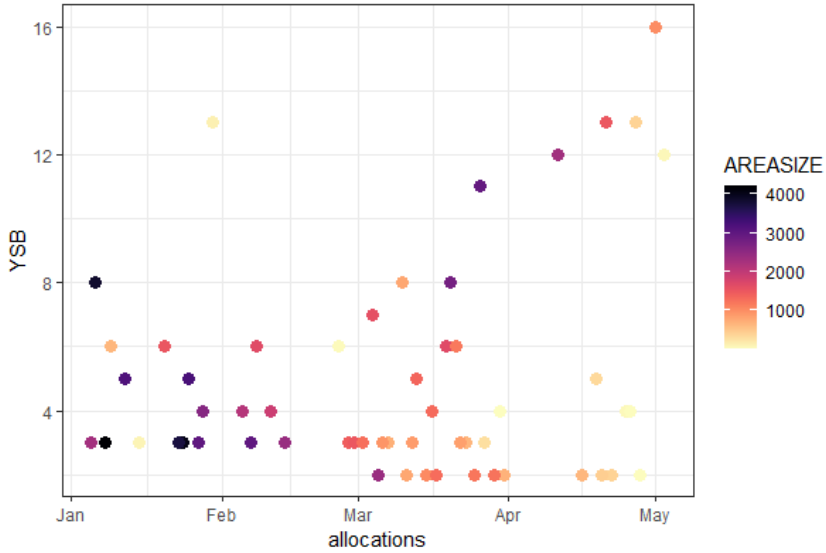
Burn allocation example 3



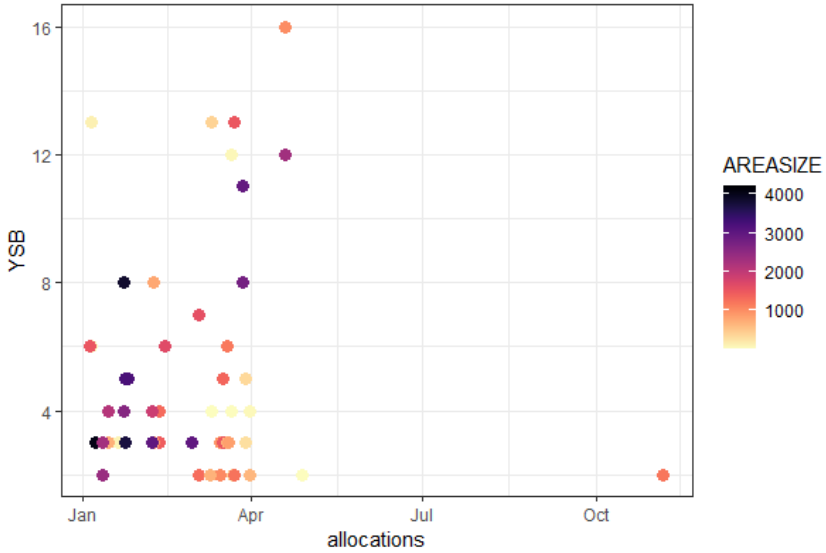
- <2 years since last burn

Allocation of all plots

Total of 56 plots that were originally burnt at Eglin AFB in 2021



Prob(within threshold) > 80%
Max # of burns per day = 1



Prob(within threshold) > 90%
Max # of burns per day = 2

Where do we go from here?

- If we want to relax burn windows, we need better understanding of which Rx parameters can be relaxed where
- Better understanding of how precipitation plays a role
- Better documentation and data collection that can be leveraged to build statistical models
- Actionable science co-produced by scientists and fire practitioners