PREDICTING THE ONSET OF RAPID DROUGHT INTENSIFICATION EVENTS

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Inspiration

Flash droughts impact millions of Americans every year

- Hard to predict
  - Worsen quickly (weeks not months)
  - Can arise in non-drought conditions
  - Can add to existing drought conditions
- Costly
  - Crop and livestock loss
  - Drinking water shortages
  - Hydroelectric energy production

Purpose

Create a tool that can predict flash drought onset

- Use modern computational techniques
- Trained on prior events
- Easy to understand
- Helpful in decision making

Planning

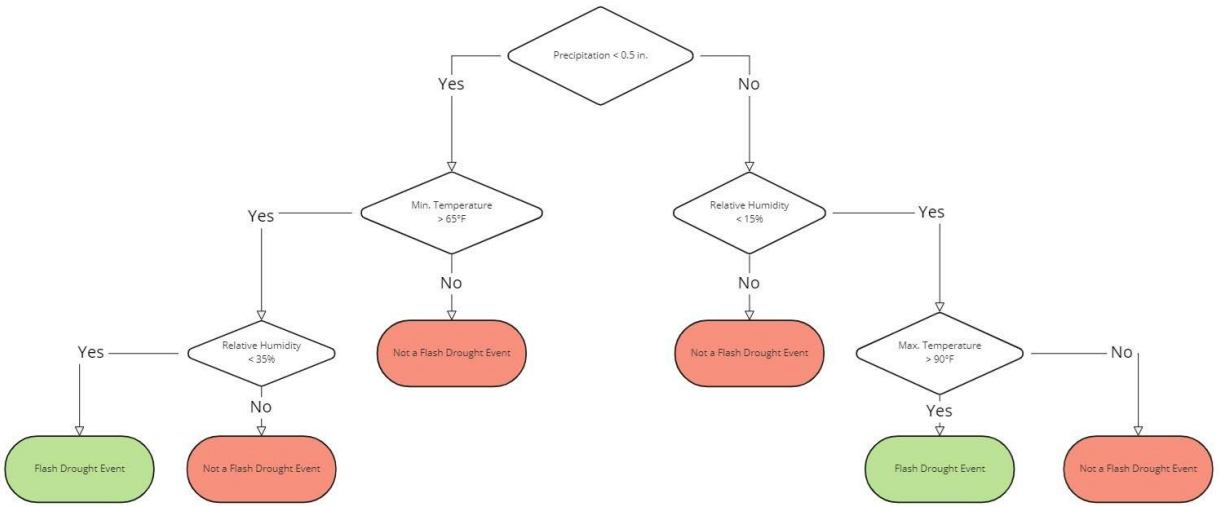
What kind of model?

- Random forest classifier
  - Computationally lightweight
  - Easy to understand
  - Good at classifying rare events (like flash droughts)

Planning

What the heck is a “Random Forest Classifier”?

- A series of decision trees
- Overall prediction based on how many trees “vote” for an outcome.



Planning

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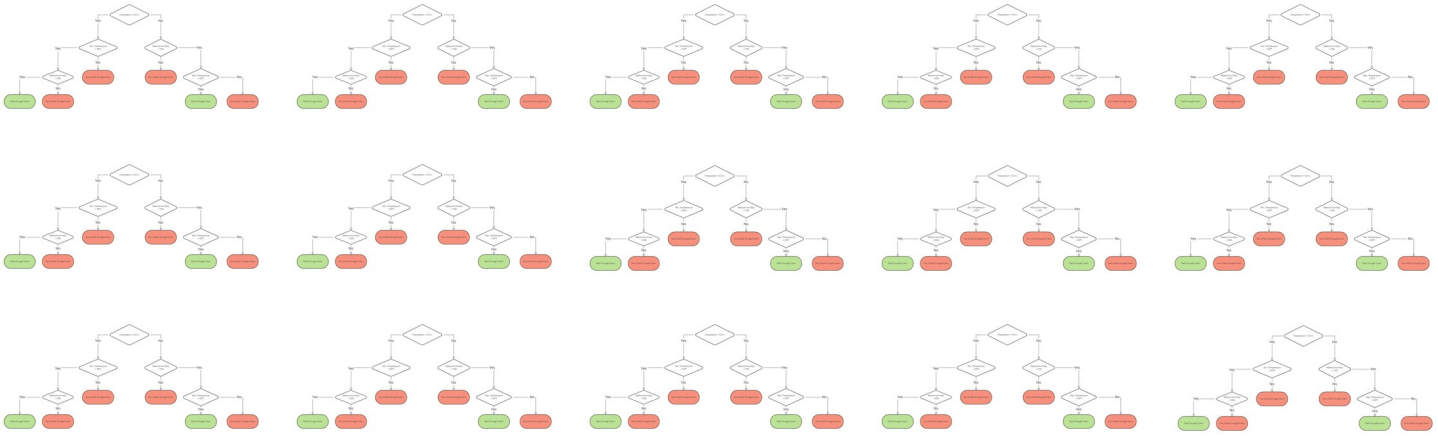


Planning

There's just one problem…

- **There isn't *one* definition of a flash drought that everyone accepts.**
- No shortage of ideas:
  - Variables:
    - Evaporation / Evapotranspiration
    - Soil moisture
    - Precipitation
    - Temperature
    - US Drought Monitor
  - Onset Rate:
    - 1 week
    - 2 weeks
    - 30 days
    - 8 weeks

Planning

We need *one* specific flash drought definition to be able to train the model.

- Need to train the model on examples of prior flash drought events.
- Need these events to have specific start and end dates and locations.
- Need to feel confident in the classification.
  - Garbage in → Garbage out

Planning

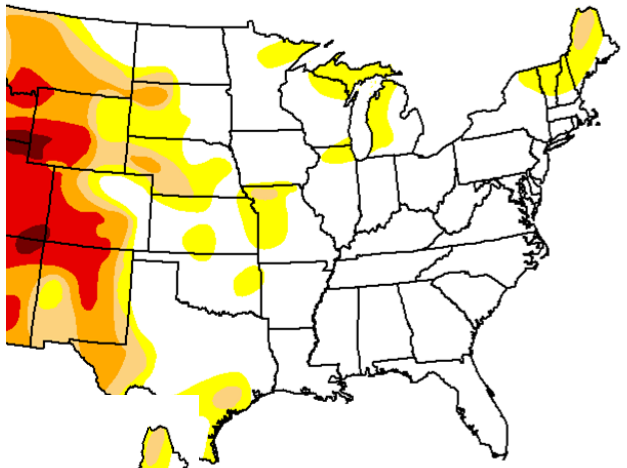
There's no perfect definition.

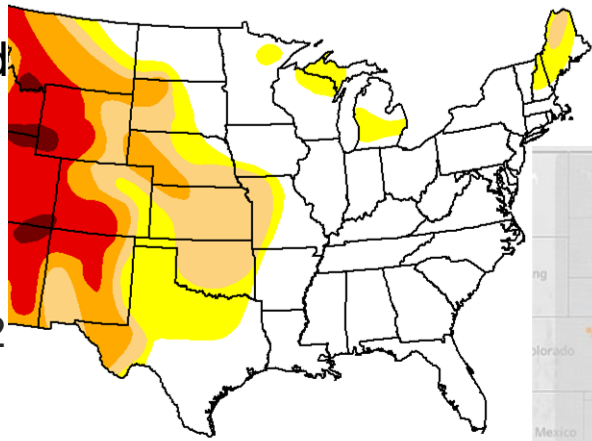
- Soil moisture
  - In situ observations are sparse
  - Location specific/sensitive
    - Spatial interpolation not helpful
- Evapotranspiration, precipitation, temperature, etc.
  - Led to spotty, inconsistent events
  - Precise but complex and inflexible
- Drought Monitor
  - Human intuition but also human fallibility
  - Only updated once per week

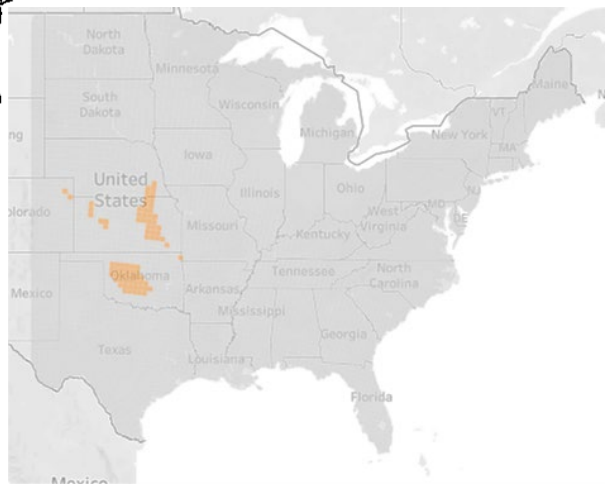
Planning

Decided to use the US Drought Monitor

- Used the definition in Pendergrass et al. (2020)
  - Produced results that agreed with extent and location of past flash drought events.
- Flash drought onset classified as:
  - 2-category increase
  - In 2 weeks or less
  - Sustained for at least another 2 weeks







Planning

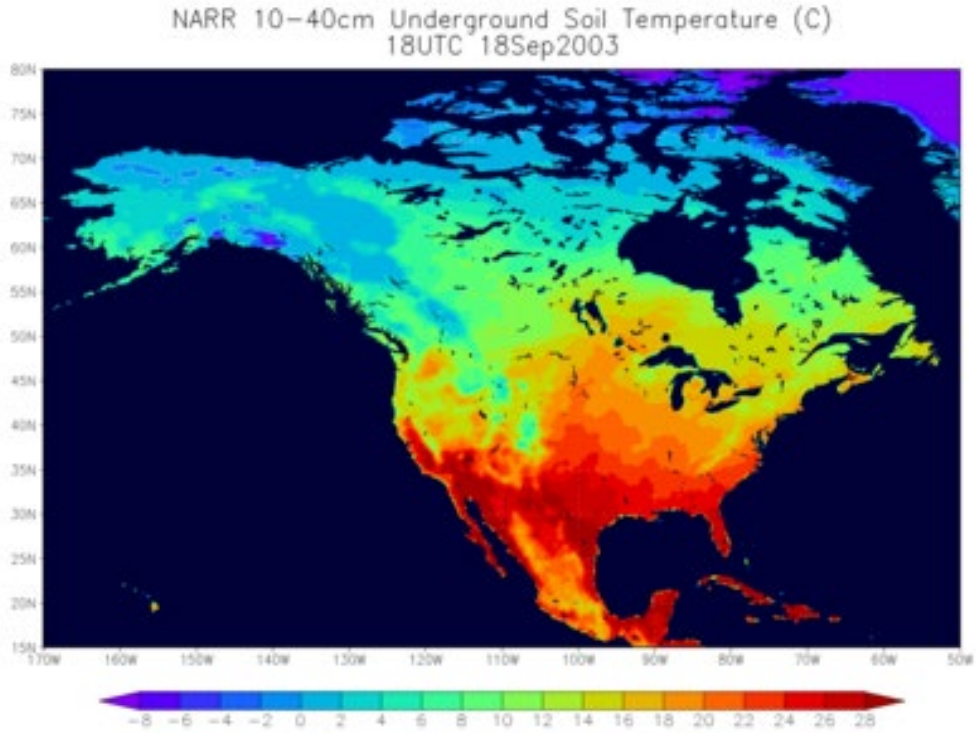
The Predictors

- We cared about conditions that caused the 2-category increase in the US Drought Monitor in ≤2 weeks.
- Decided to use environmental conditions over that same 2-week period.
  - The conditions that led to the 2-category increase.

Training and Testing

Building the Model

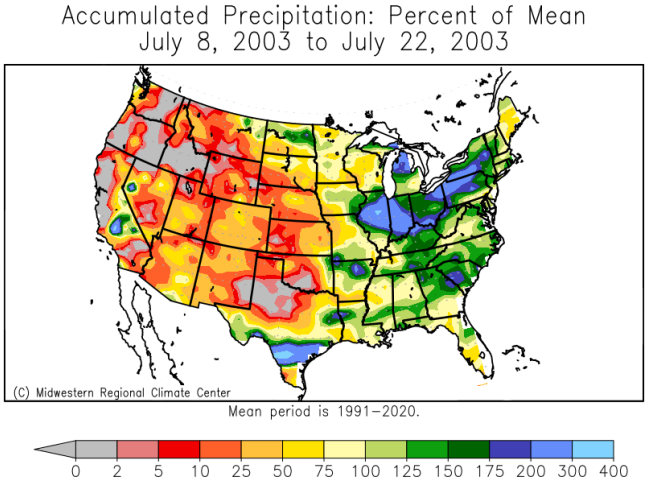
- Used North American Regional Reanalysis (NARR) data for environmental conditions.
- Gave the model millions of datapoints to learn from.
- Model trained on these data and “learned” what conditions were required for a flash drought to occur.

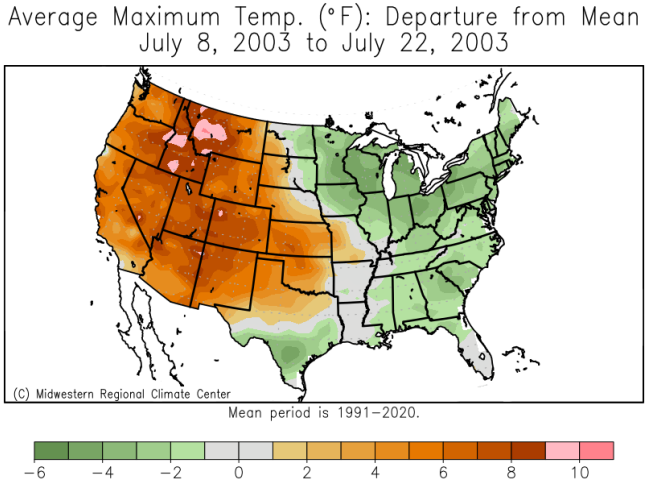


Training and Testing

Predictors Used:

- Latitude
- Longitude
- Day of the year
- Temperature
- Precipitation
- Dew point
- Relative humidity
- Mean Sea Level Pressure
- Air pressure
- Wind speed and direction





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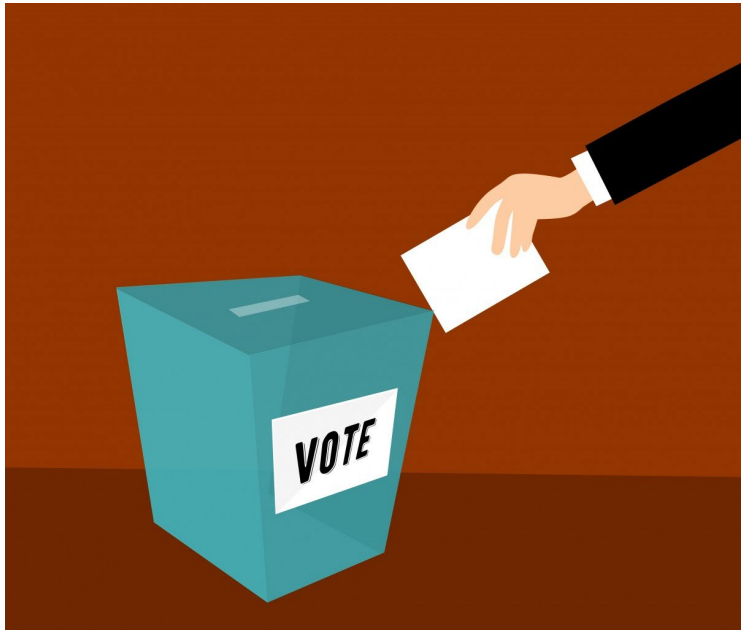
Training and Testing

One important note…

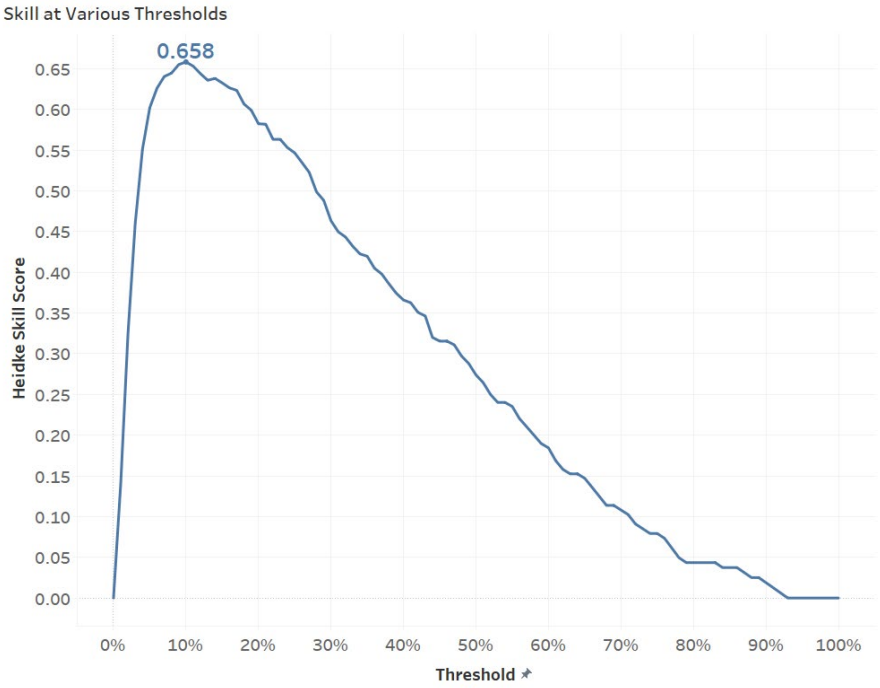
- "Vote" threshold needed doesn't have to be 50%...
- Can change this threshold to fine-tune the sensitivity of the model and increase accuracy.



Training and Testing

Preliminary Results

- Using cross validation on historical data:
  - Best “vote” threshold was about 10%
    - Heidke Skill Score = 0.658
  - Probability of detection = 61.6%
  - False alarm rate = 24.1%
  - About 76% of events exceeding this threshold were flash drought events.



Implementation

Now what?

- Time to implement the model into something useable on a daily basis.
- What forecast data to use?
  - GFS
    - Updated regularly
    - Includes all the variables we trained with
    - Forecast goes out at least 14 days
      - Required since the model was trained to use 2 weeks of data for a prediction.

Implementation

The raw prediction output was difficult to interpret.

- Percent of trees in forest ≠ Probability of flash drought
- A simple “yes” or “no” forecast isn’t ideal.
- Would be better if we could show risk levels
  - Low, Medium, High risk, etc.

Implementation

Looked to the testing results for guidance.

- Risk levels should be based on a risk probability.
- Can estimate a probability using prior flash drought events.
  - "In the past, what percent of flash drought events happened when **n**% of trees predicted a flash drought?"

Implementation

Risk Levels:

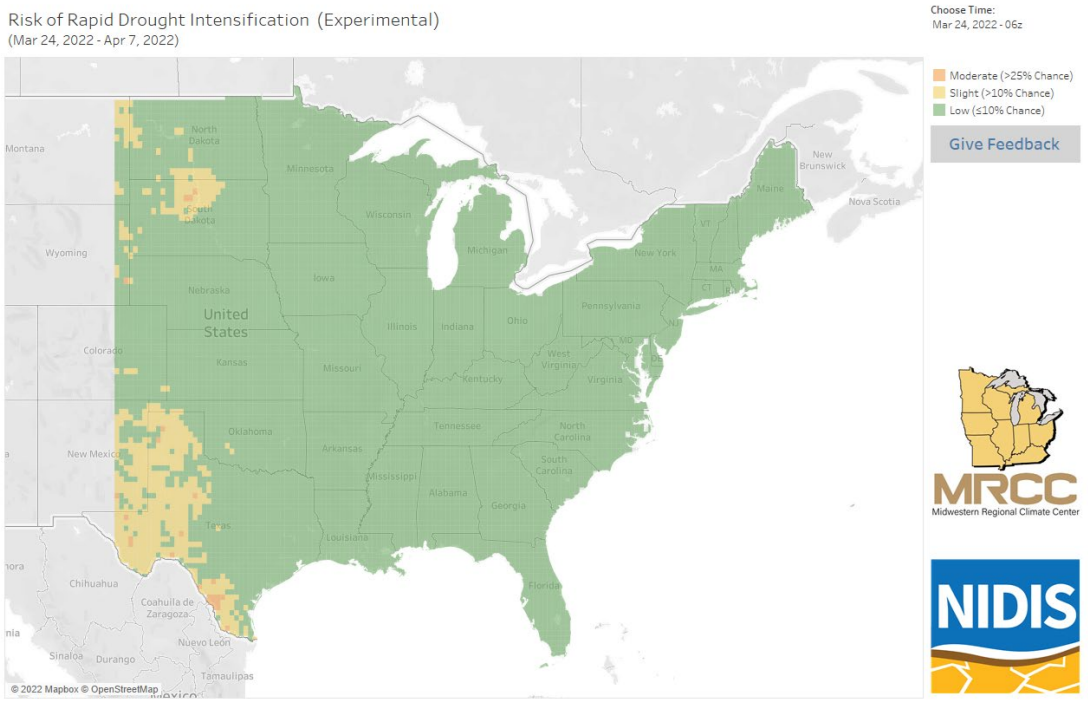
- Low:
  - ≤ 10% risk
- Slight:
  - > 10% risk
- Moderate:
  - > 25% risk
- High:
  - > 50% risk
- Very High:
  - > 75% risk
- Extreme:
  - > 90% risk

Risk Level	Probability of Detection	False Alarm Rate
Low	100 %	100 %
Slight	89.8 %	92.3 %
Moderate	82.9 %	79.8 %
High	71.1 %	47.8 %
Very High	58.7 %	25.1 %
Extreme	43.2 %	10.5 %

Working Prototype

Success!

- We have a finished tool!
- Updates every 6 hours
  - Shortly after newest GFS run is available.



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Working Prototype

A few things to note…

- The model uses GFS *forecast* data to make a prediction.
  - Prediction only as good as the GFS's prediction
  - If the 2-week GFS forecast changes, the prediction will change.
- Model was only trained for events in April – October
  - Limited skill outside of this window
- Prediction is the likelihood of flash drought *onset*.
  - Not predicting if a current flash drought event will persist

Next Steps

More testing is needed.

- All model performance testing was done on NARR reanalysis data.
  - Yet to be seen how model handles GFS forecast data.
- Test other variables in model
  - Drought indices
- Notification system
  - Users can sign up to get alerts when their location is at risk of flash drought onset.

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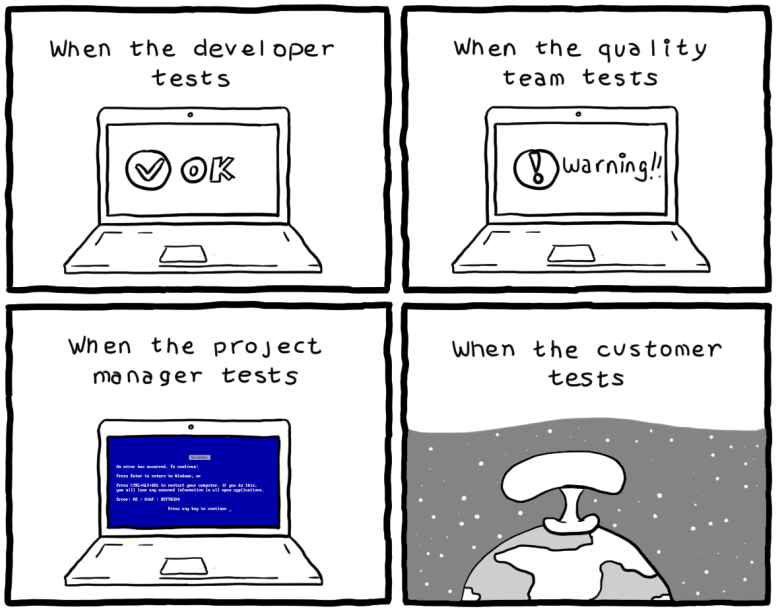
Next Steps

We need your help!

- We'd love to have you try the tool for yourself!
- Try it out over the next few months and let us know your thoughts.
  - Ideas and suggestions
  - Bugs and other issues
  - Bad or suspicious forecasts



https://mrcc.purdue.edu/MWDEWS/flashdroughttool.html