Setting the Stage

- What makes this unique?
  - Research has shown relationships between ecoregions and climate
  - Yet, the found relationships were not being used in decision making for resource allocation nationally
  - Applied design-thinking to develop the algorithm shown here to facilitate technology transfer to decision making

- Funded by Jet Propulsion Laboratory under our Research and Technology program and motivated by conversations with the Global Change and Energy Office increasing applications value of remote sensing

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Fire Danger from Earth Observations (FDEO): Use of Satellite Observations to Forecast Wildfire Danger

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3) US Forest Service
4) National Interagency Fire Center

NDRC July 1st 2020

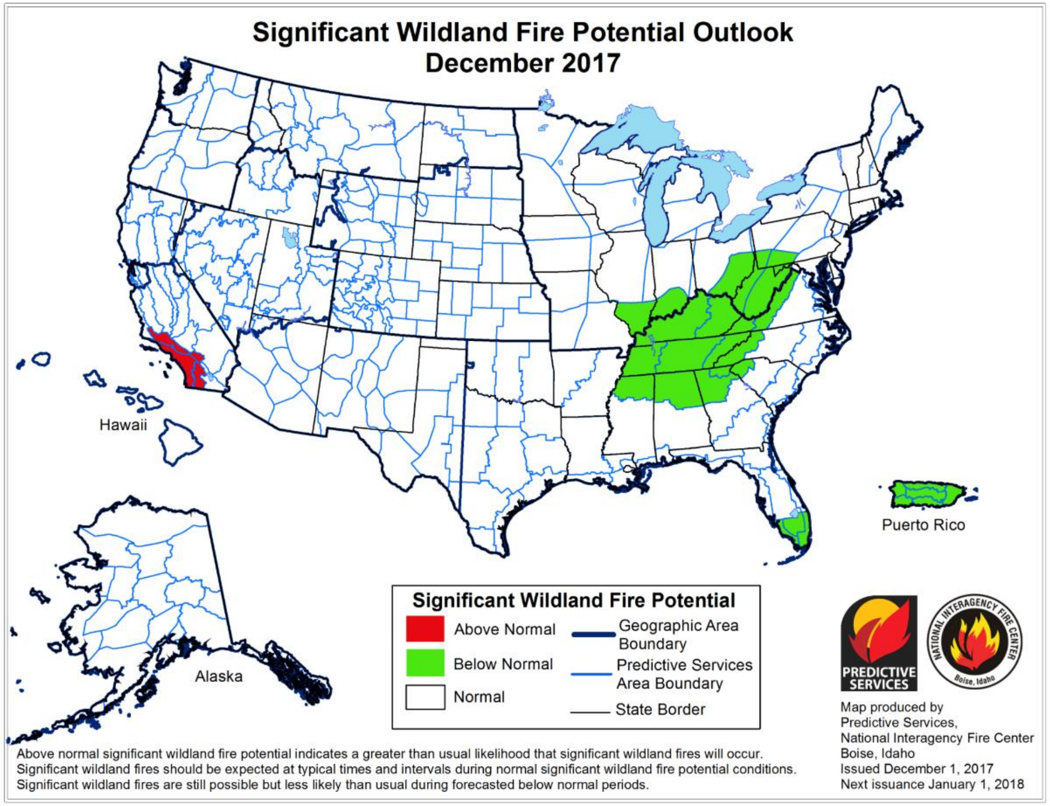
Problem Statement

- Fires occur synchronously across the US
- However, there are limited fire management resources
- One agency determines allocation of resources both nationally and internationally: National Interagency Fire Center (NIFC)
- Use "Preparedness Levels" to communicate allocation of resources

PL	Description
1	local resources with little or no national support
2	Local resources insufficient but national resources available
3	All national resources deployed and priority areas established
4	National resources are heavily committed and trades are being made based on mobilization of resources to areas of highest demand
5	All resources deployed and trades between geographic areas. Emergency measured deployed.

Current State

- Use expert knowledge and meteorological forecasts to draw perimeters on a map for 1-month, 2-month and 3-and-4-month fire danger forecast

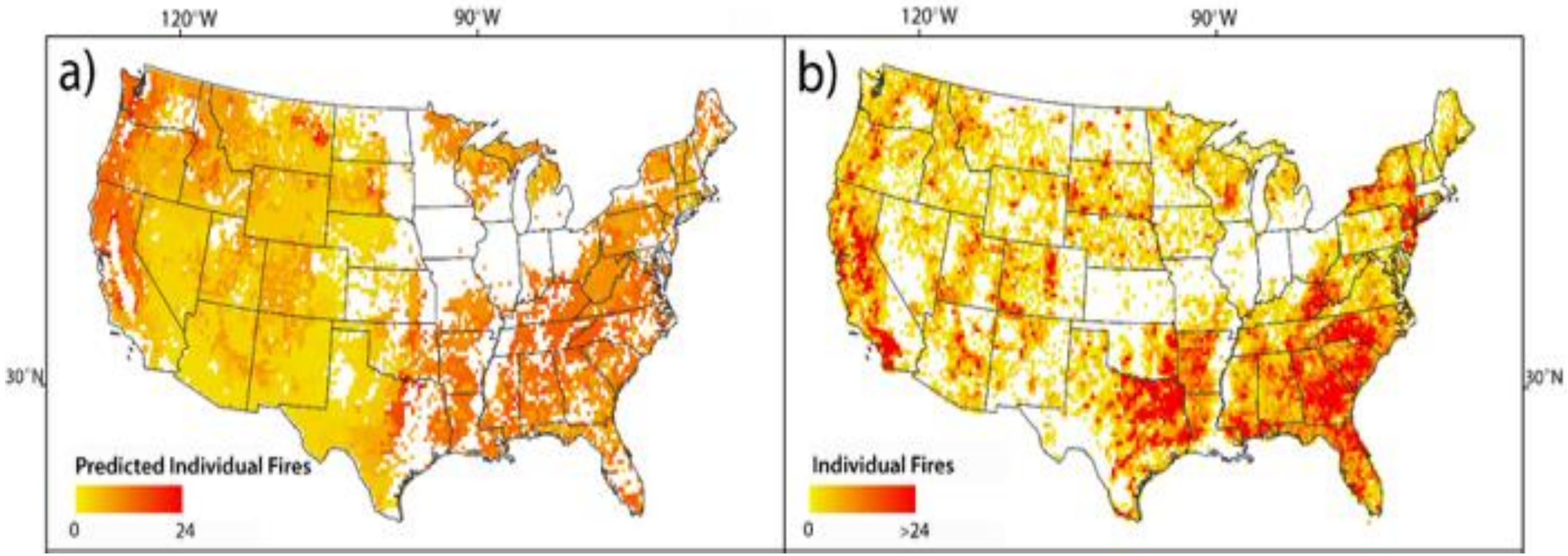


✓ Subjectivity involved

✓ Vague definition of normal according to NIFC managers

Deterministic Solution

- Recent case studies provide examples of hydrologic variables (e.g., soil moisture or vapor pressure deficit) to hindcast fire danger (area burned or number of fires)



Jensen et al., 2017, The sensitivity of US wildfire occurrence to pre-season soil moisture conditions across ecosystems, Environmental Research Letters

Data Input

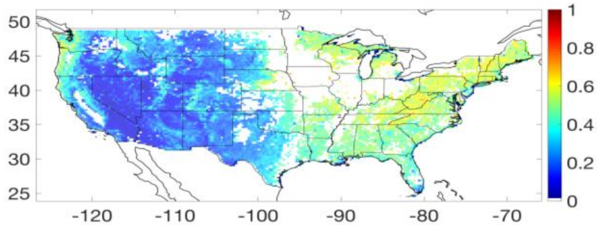
- Monthly NASA AIRS Vapor Pressure Deficit (VPD)
- Monthly NASA GRACE assimilated Soil Moisture (SM)
- Monthly MODIS Enhanced Vegetation Index (EVI)
- USFS fire burned area data (FPA-FOD)
- USGS land-cover map

✓ *Spatial Resolution: 0.25°*

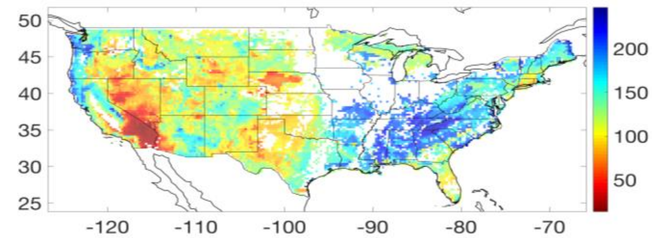
✓ *Data Length: 2003-2013*

Data Input

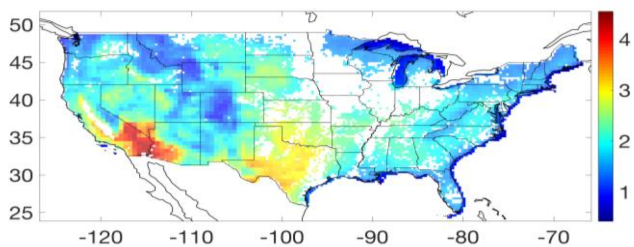
Aug 2010 Enhanced Vegetation Index (EVI)



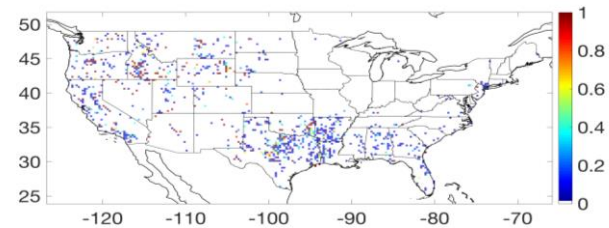
Aug 2010 Soil Moisture



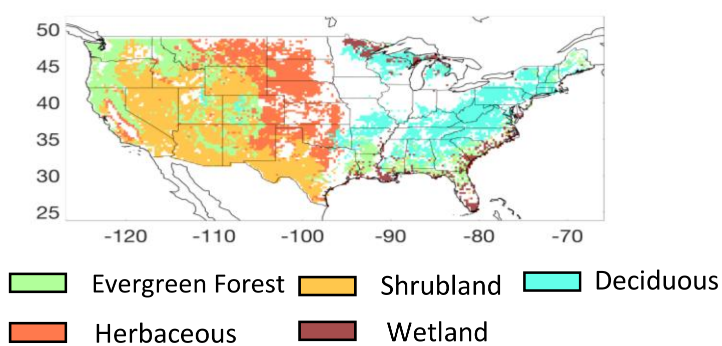
Aug 2010 Vapor Pressure Deficit (VPD)-kPa



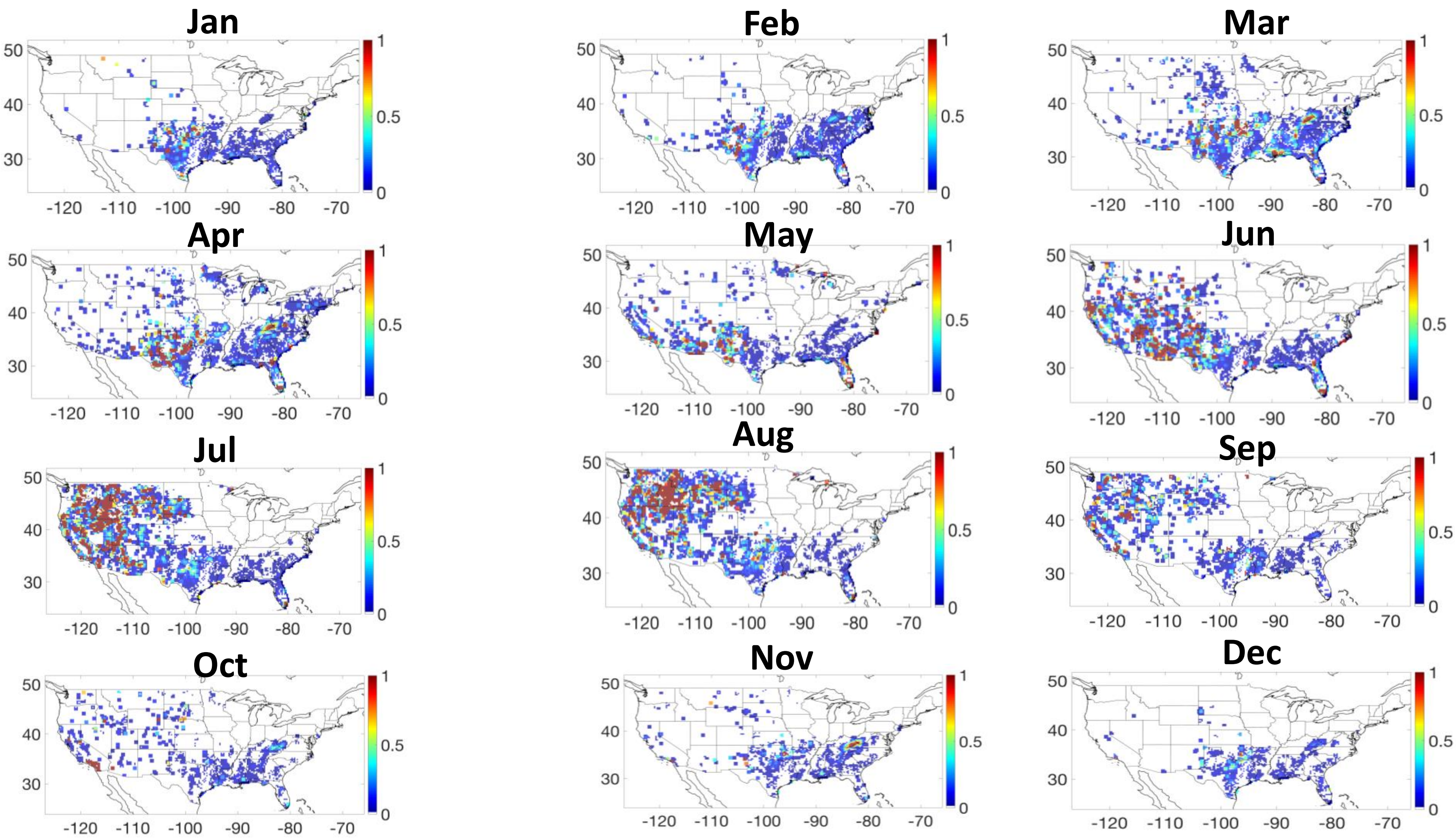
Aug 2010 FPA Burned Area-Sq Km



Land-Cover



Average Burned Area Sq Km



Convert SM, VPD and EVI to Drought Indicators

The Empirical Gringorten probability:

$$p(x_i) = \frac{i - 0.44}{n + 12}$$

i Rank of non zero data from the smallest (SM, EVI), largest (VPD)

n Sample size

x Data vector

IF DI > 0 → Wet

IF DI < 0 → Dry

$$DI = \phi^{-1}(p(x_i))$$

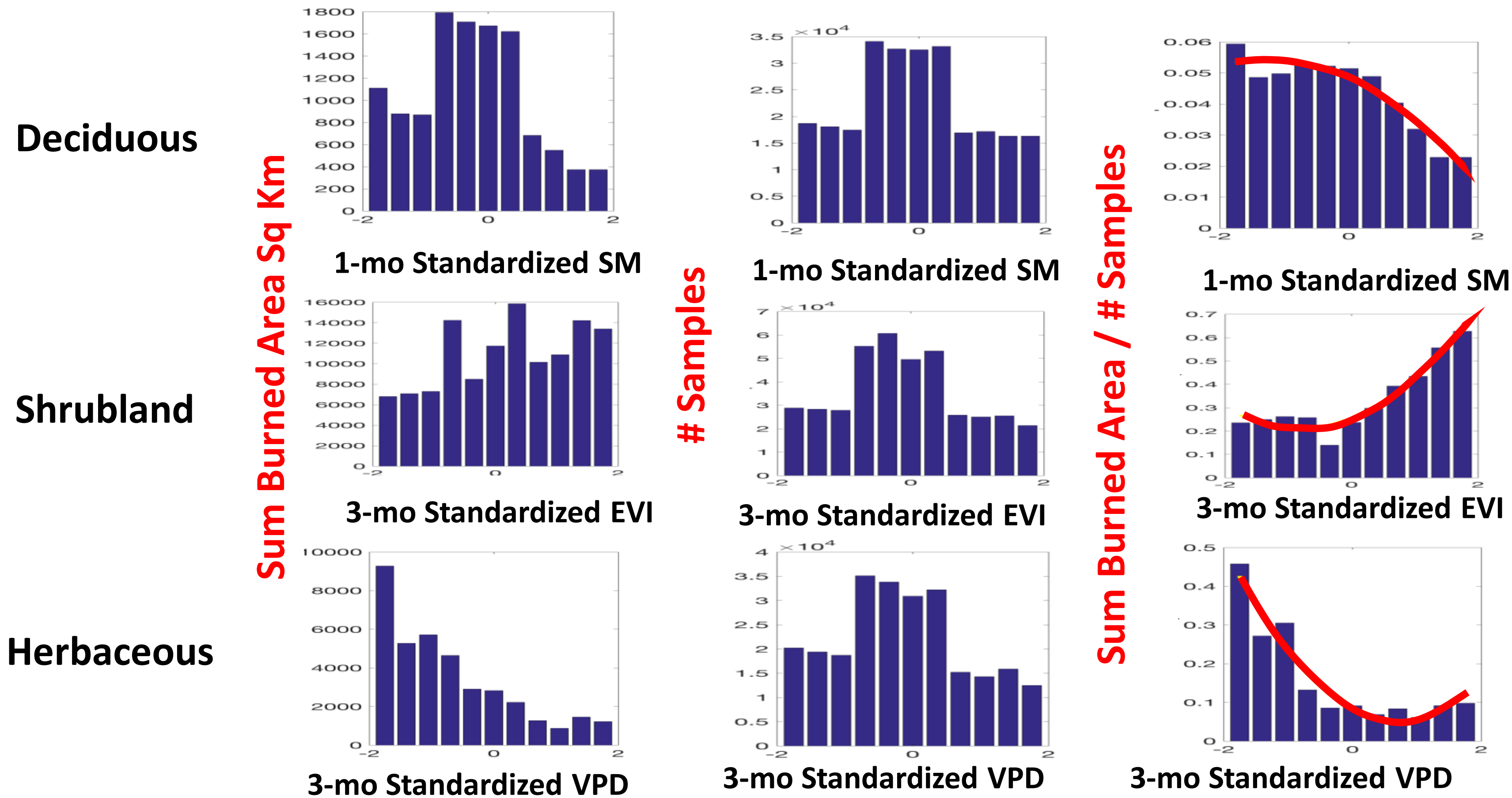
ϕ Standardized normal distribution function

SI Standardized Index

Burned Area Forecast

- **Determine the variables with best relationship to fire burned area**

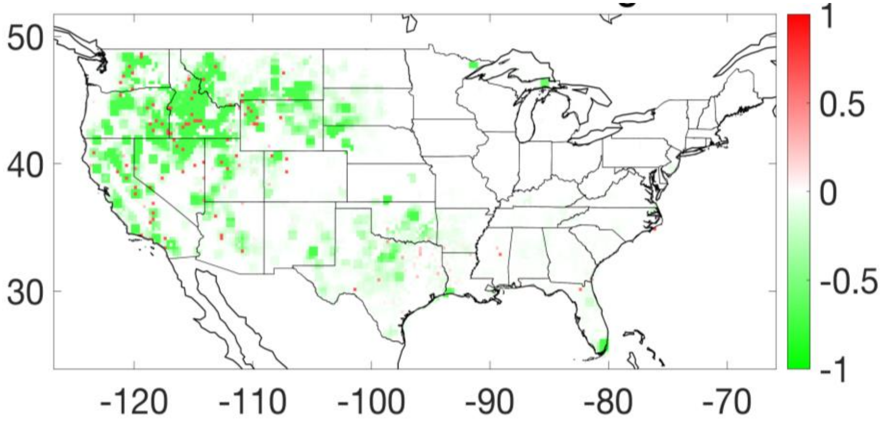
$$BA\ Forecast = \frac{Sum\ Burned\ Area\ (Sq\ Km)}{\#\ Samples}$$



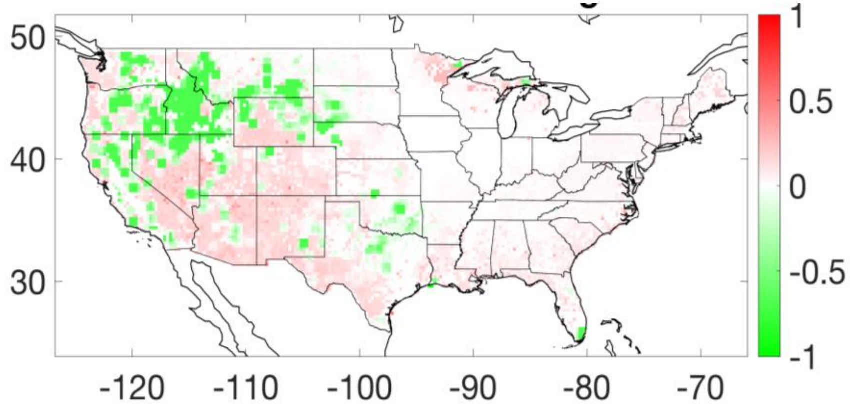
Burned Area Anomalies

Burned Area
Anomalies from the climatology
Aug 2013

Observation



Prediction



- **To convert burned area forecast to categorical fire danger, we need to first derive the anomalies from the climatology to see if above or below normal**

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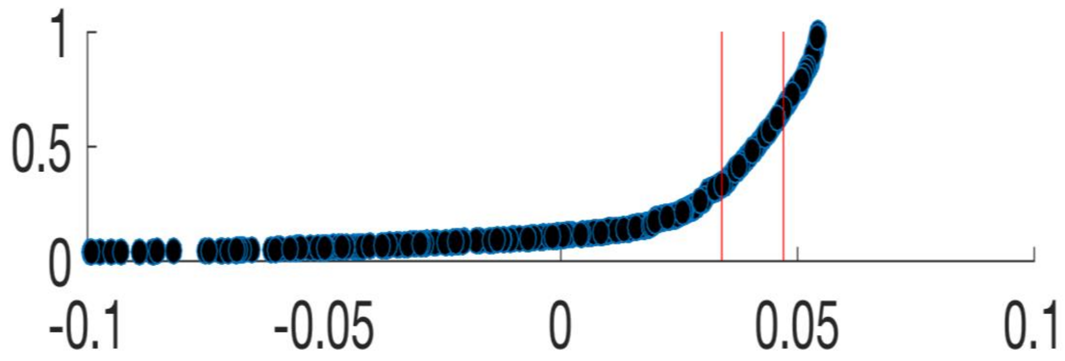
Burned Area Distribution

- An example of Cumulative distribution of prediction anomalies
- In the previous plot, we use 0 as reference for above and below normal
- We see that 0 does not represent the middle of the distribution (”normal conditions”)
- We instead divide the data into 3 probability ranges so that the observations and predictions can be compared more accurately



Cumulative distribution of prediction anomalies in Deciduous

Burned Area Distribution

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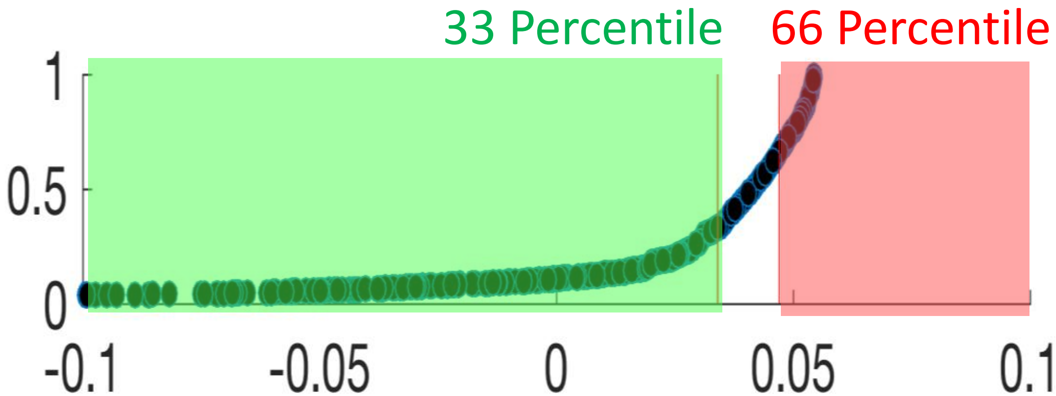
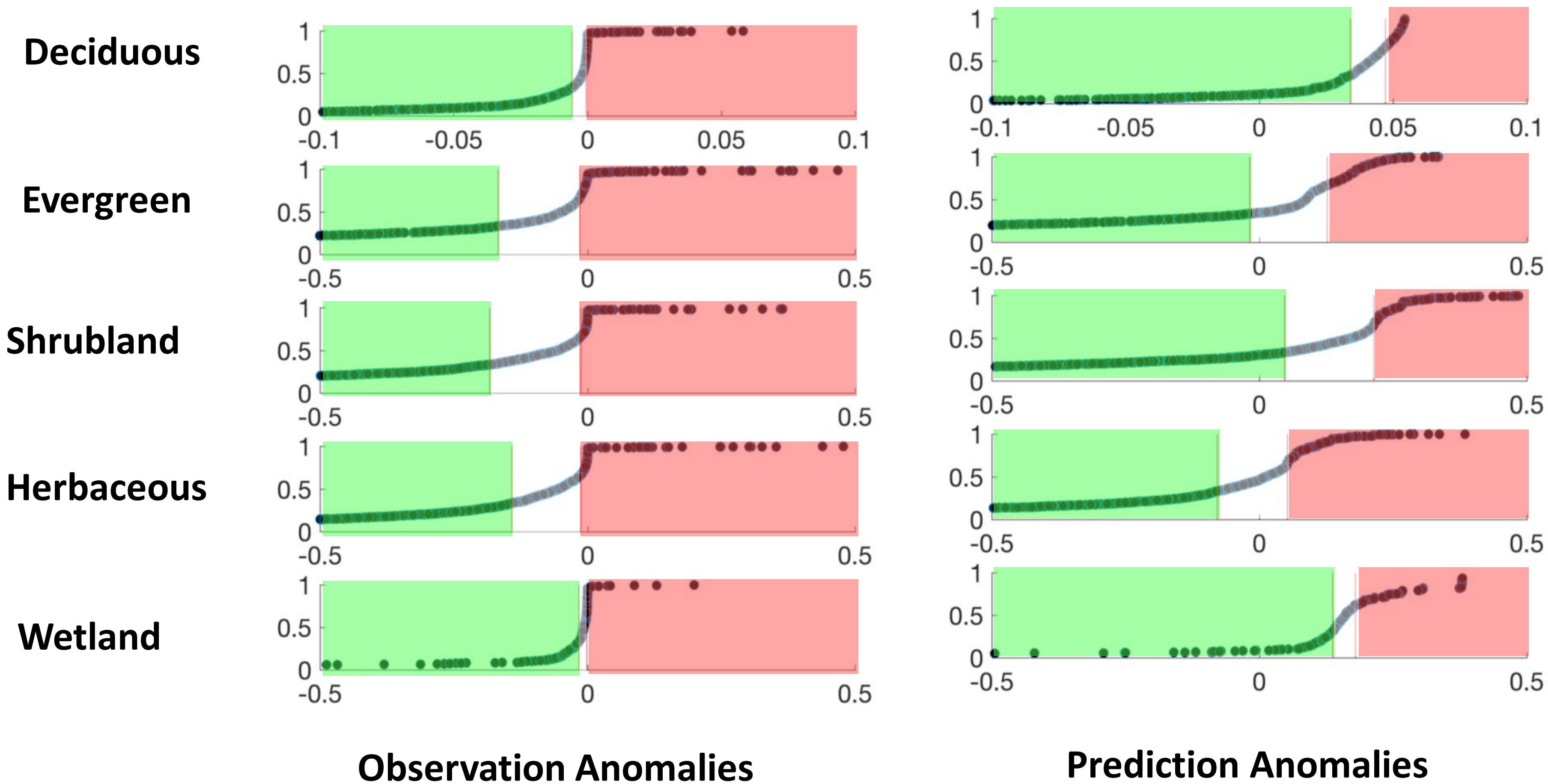


Cumulative distribution of prediction anomalies in Deciduous

Burned Area Distribution

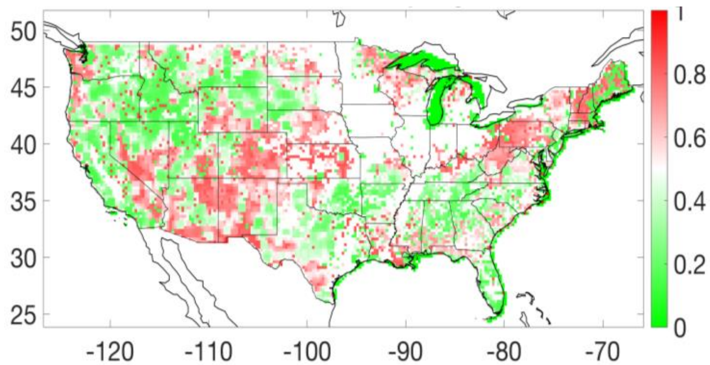
Match Categorical BA thresholds Between Prediction and Observation AUG 2013



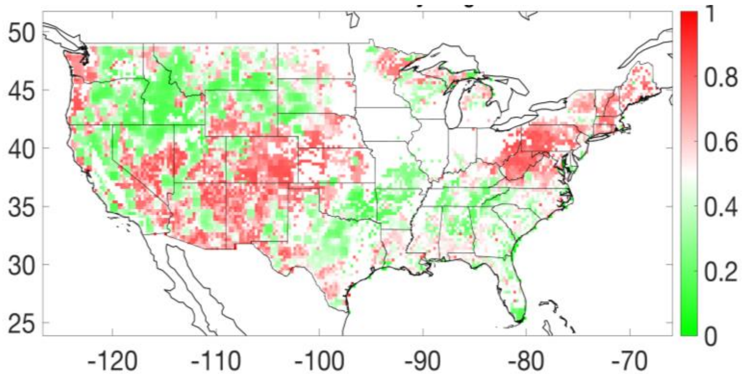
Results

Burned Area Aug 2013

Observation



Prediction



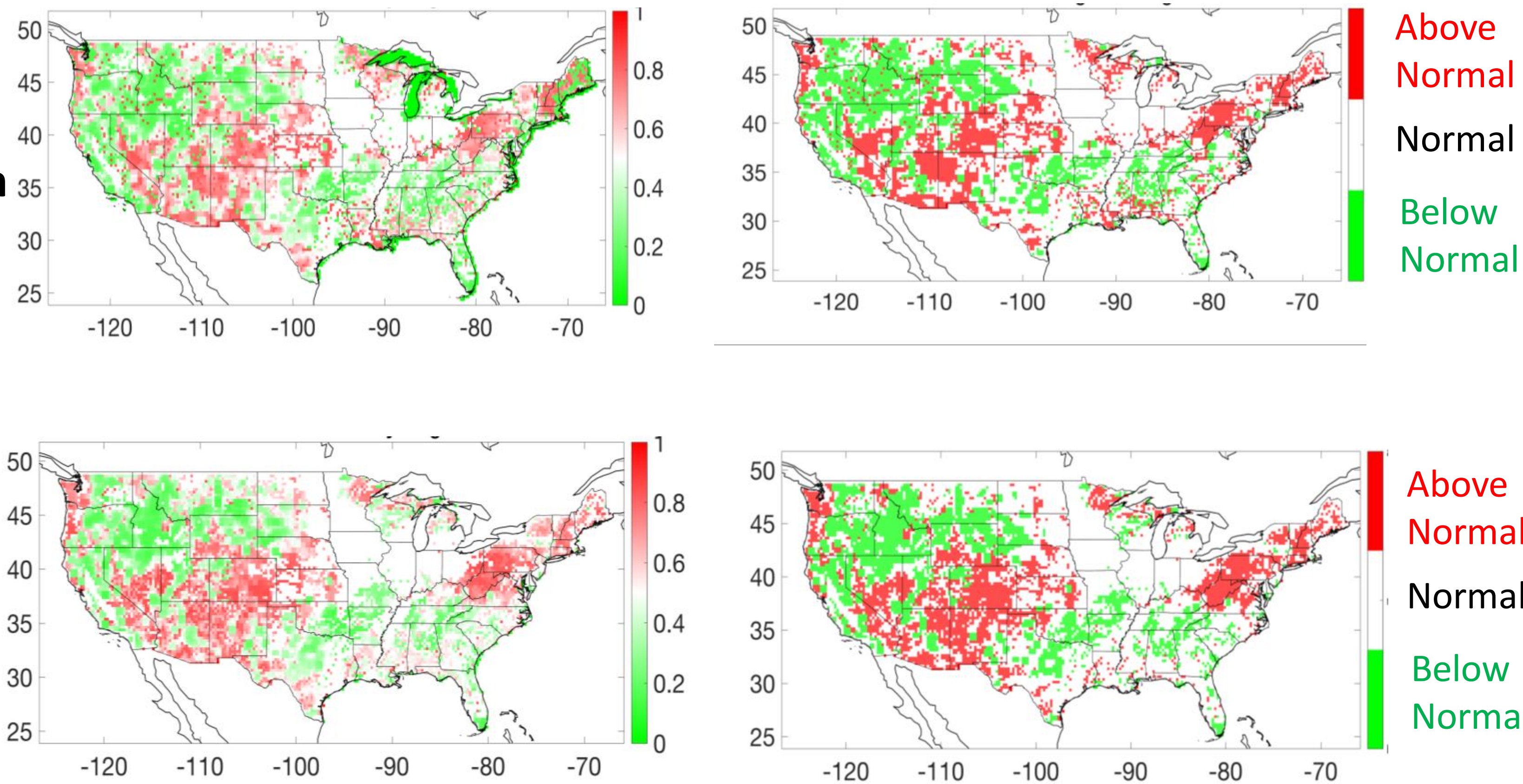
Probability

Results

Burned Area Aug 2013

Observation

Prediction



Probability

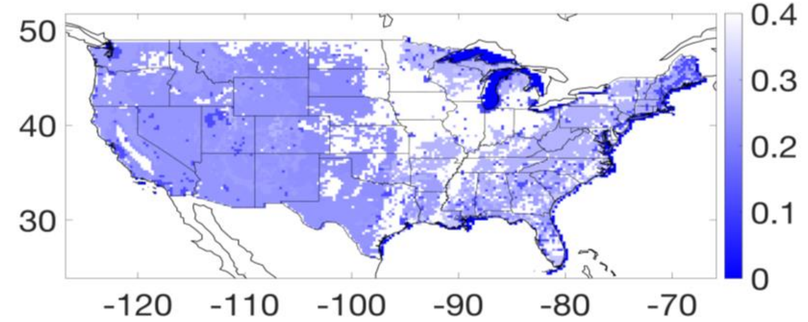
Categorical

Validation

Burned Area Aug 2013

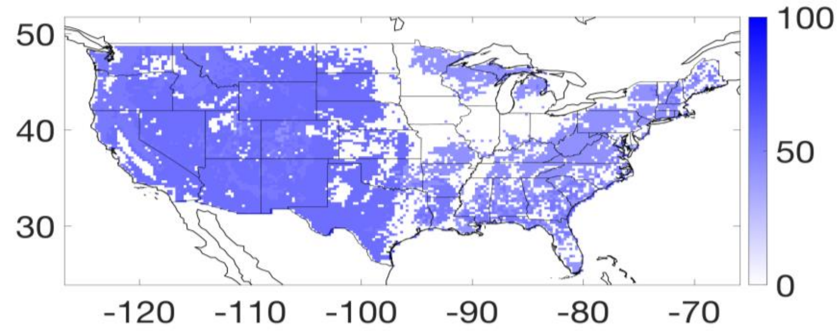
$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} {e_i}^2}, \quad e_i = p_i - o_i$$

RMSE

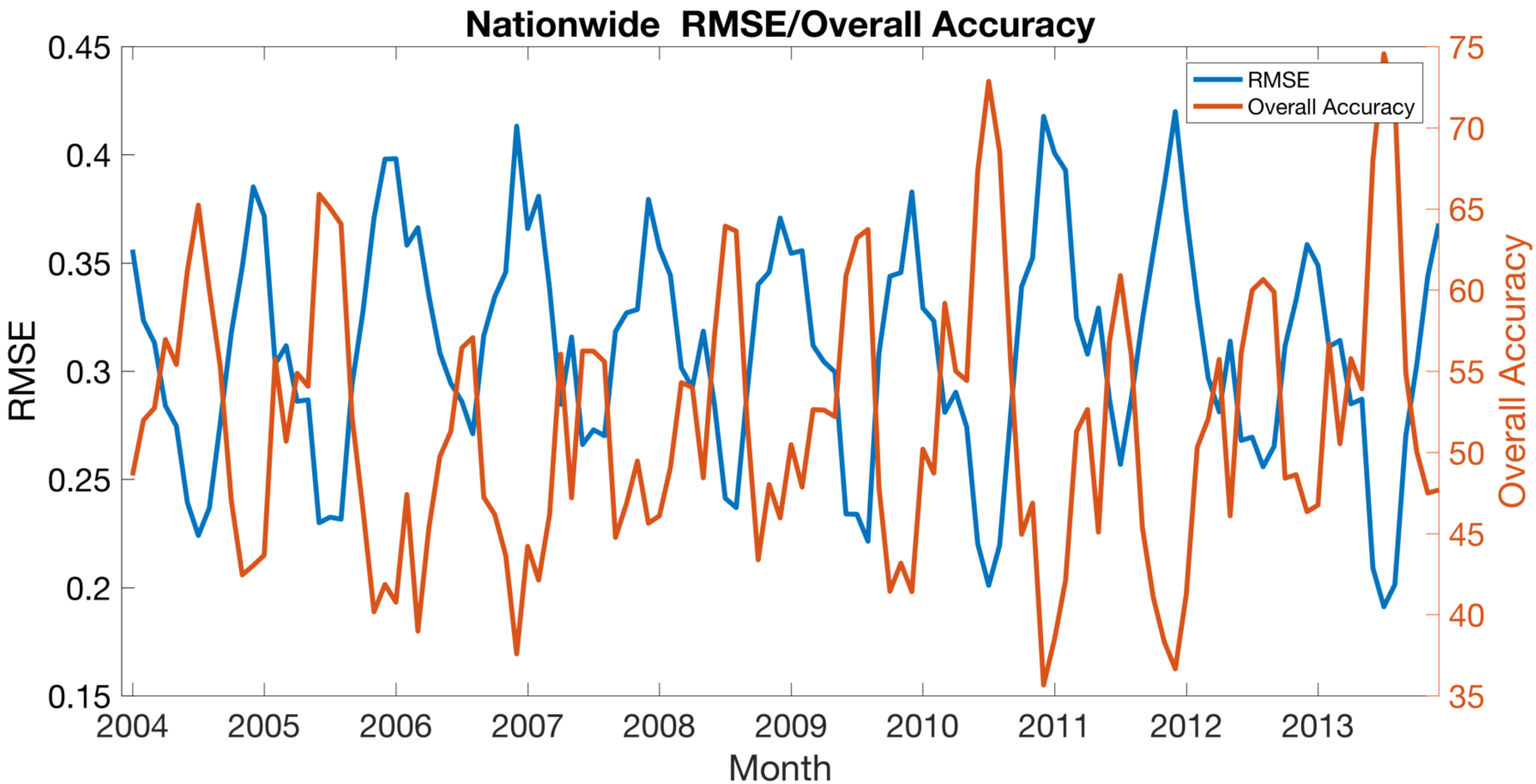


$$OA_{LC} = \frac{Number\ of\ Correctly\ Classified\ Grids}{Total\ Number\ of\ Grids}$$

Overall Accuracy



Validation



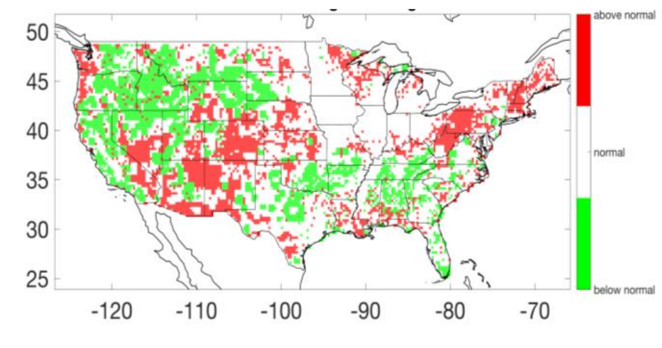
Time series of RMSE and OA

We see higher OA and lower RMSE in spring and summer time (fire season)

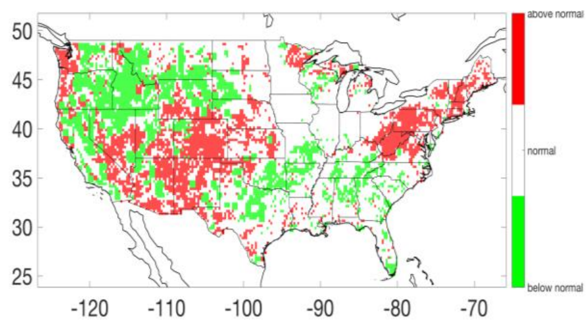
NIFC Comparison

Burned Area Aug 2013

Categorical Observation



Categorical Prediction



NIFC Categorical Prediction

Farahmand, A.; Stavros, E.N.; Reager, J.T.; Behrangi, A. Introducing Spatially Distributed Fire Danger from Earth Observations (FDEO) Using Satellite-Based Data in the Contiguous United States, 2020, *Remote Sensing*, *12*, 1252, doi:10.3390/rs12081252.

Conclusion

- We built a gridded monthly fire danger prediction model based on soil moisture, vapor pressure deficit and enhanced vegetation index input

- The results show that the model can predict fire danger with relatively low uncertainty and high accuracy especially in the spring and summer months

- Had we had more historical fire samples in the fall and winter months, the model could be improved

Next Steps

- Transition to operations with USFS and NIFC engagement
- Testing and validating FDEO with post 2013 fire observation data (e.g. MODIS Active Fire)
- Integration of the next generation of sensors as data inputs for future continuity

  MODIS -> VIIRS, GRACE -> GRACE-FO, AIRS -> CrIS

- Operationalize FDEO with the support of other agencies e.g. NASA, JPL

Next Steps

- Develop a gridded wildfire fire prediction product in a global scale
  - FDEO Algorithm scalable for global domain
  - The model validation is pending globally
  - Looking for funding opportunities

    Seasonal to Subseasonal Wildfire Danger Forecasting using SMAP Soil Moisture Products, 2020-2023, NASA, $450000, PI, under review

Thanks!