National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Using NASA Satellite Observations to Map Wildfire Risk in the United States for Allocation of Fire Management Resources

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Problem Statement

Fires occur synchronously across the US and we have limited fire management resources

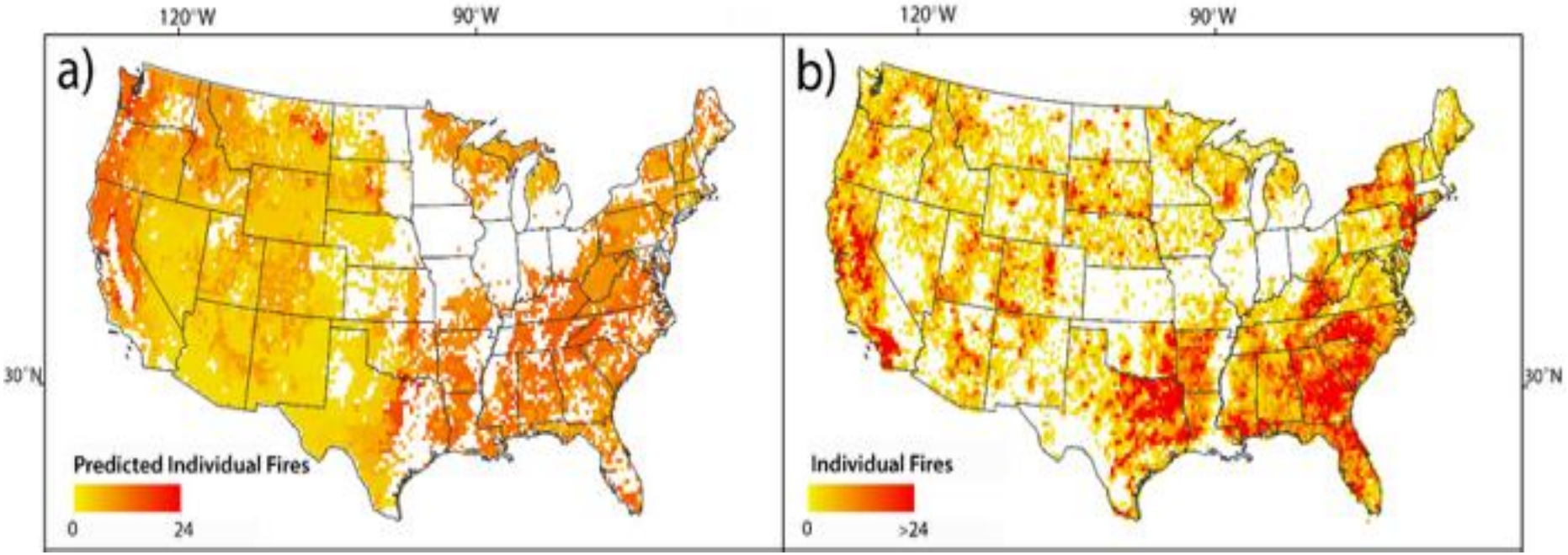
- One agency determines allocation of resources both nationally and internationally: National Interagency Fire Center (NIFC)
- They use “Preparedness Levels” to communicate allocation of resources

PL	Description
1	local resources with little or no national support
2	Local resources insufficent 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.

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

Solution

preliminary analyses and many case studies in literature provide examples of how hydrologic variables (e.g., soil moisture or vapor pressure deficit) can hindcast fire danger (area burned or # of fires)



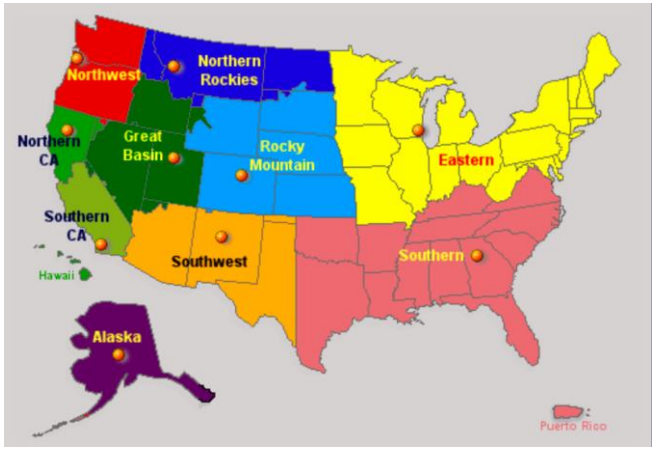
Task

Develop an operational algorithm for 1-month, 2-month and 3-and-4-month forecasts of fire danger (area burned) using NASA satellite hydrologic variables (AIRS, SMAP, GRACE)

Step	Description
1	Develop linear regression models based on different combinations of SM and VPD: Y = anomaly area burned X1 = prior months VPD X2 = prior months SM
2	Calculate statistical metrics to select the best model
3	Adjust climatological area burned by anomalous area burned

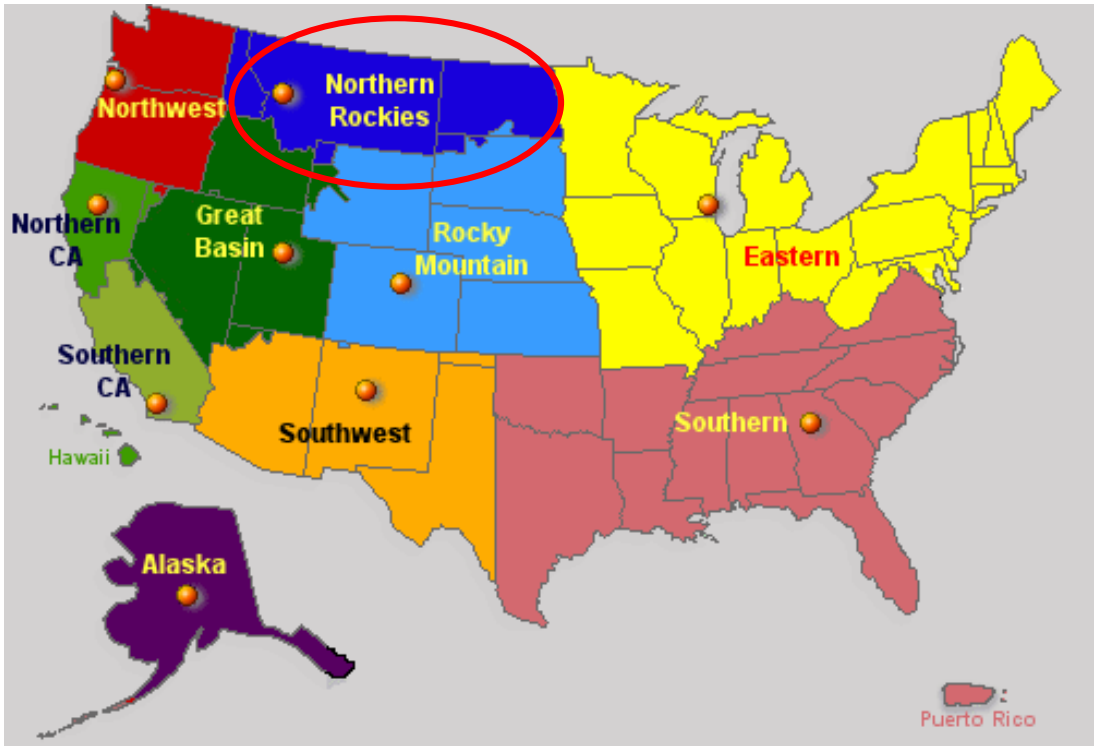
1) performed at the Geographic Area Coordination Center scale to:

- Match NIFC deployment
- Understand regional differences in climate

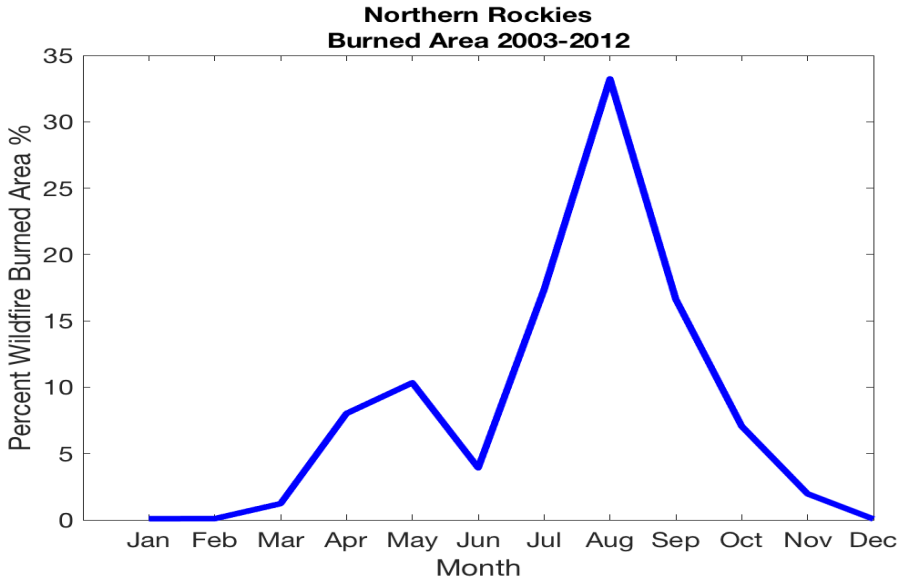


Datasets and Study Area

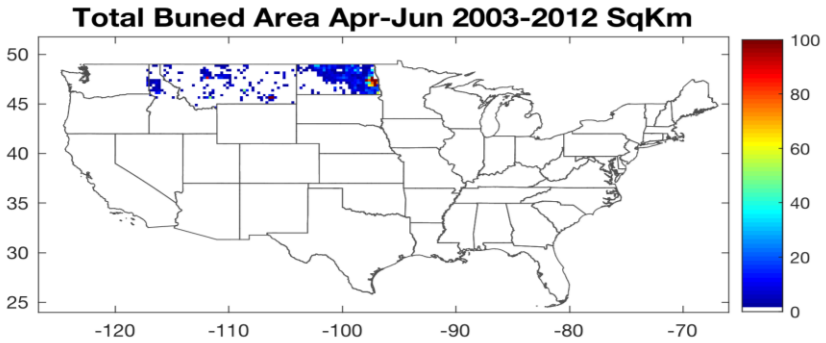
- Monthly GRACE-assimilated top 2-cm surface Soil Moisture
- Monthly AIRS Vapor Pressure Deficit (VPD)
- Monthly fire Burned Area GFED (Global Fire Emissions Database)
- Data Spatial Resolution: 0.25 ° , Data Length: 2003-2012

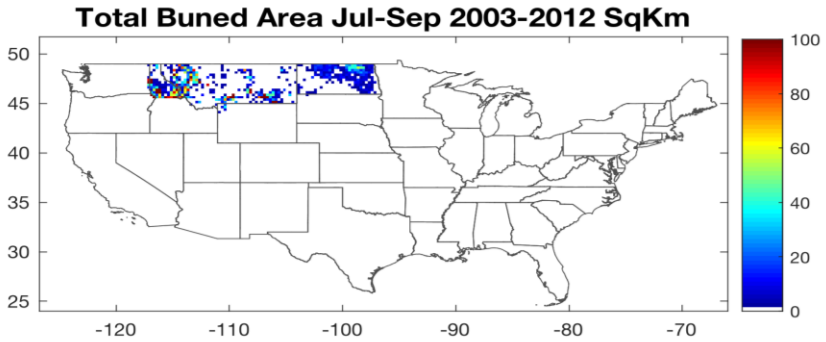


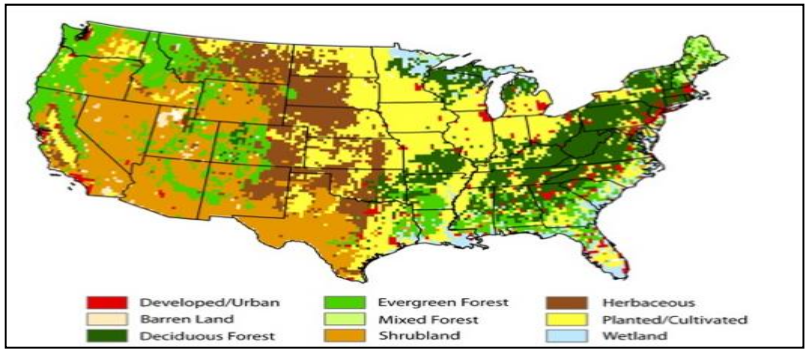
Climatology and Spatial Distribution of Wildfire activity in the Northern Rockies



Climatology of the region







Spatial Distribution of Wildfire Activity

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Methodology

Step 1: For each month, build a linear regression model based on different combinations of prior n-month lead Vapor Pressure Deficit (VPD) and n-month lead Soil Moisture (SM)

$$(\boldsymbol{Burned\ Area})_{\boldsymbol{anomaly}} = \boldsymbol{a} + \boldsymbol{b} \times (\boldsymbol{VPD})_{\boldsymbol{anomaly}} + \boldsymbol{c} \times (\boldsymbol{SM})_{\boldsymbol{anomaly}}$$

Step 2: Calculate Nash-Sutcliffe for each month:

$$E = 1 - \frac{\sum_{i=1}^{n}\left(X_{obs,i} - X_{model}\right)^2}{\sum_{i=1}^{n}\left(X_{obs,i} - \overline{X_{obs}}\right)^2}$$

n is total number of observations, X_{obs} is observation and X_{model} is model simulation and $\overline{X_{obs}}$ is mean of observations

- Calculate weighted Nash-Sutcliffe for the entire year:

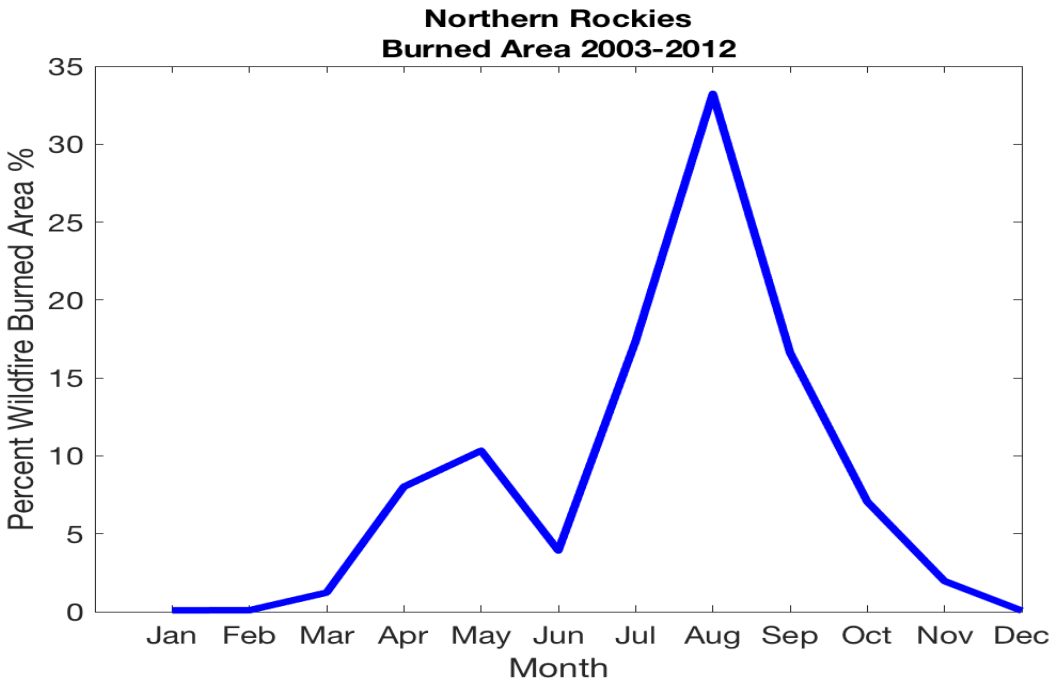
$$E_w = \sum_{j=1}^{12} E_j \ * \ fire\ climatology_j$$

where j is month number and $climatology_j$ is historical percent of fires burned in month j

- Best model: Largest E_w

Methodology

Step 2:



Month	Nash-sutcliffe
Apr	0.36
May	0.12
Jun	0.12
Jul	0.76
Aug	0.69
Sep	0.57
Oct	0.81
Nov	0.25
Dec	0.11
Weighted Sum	**56.61**

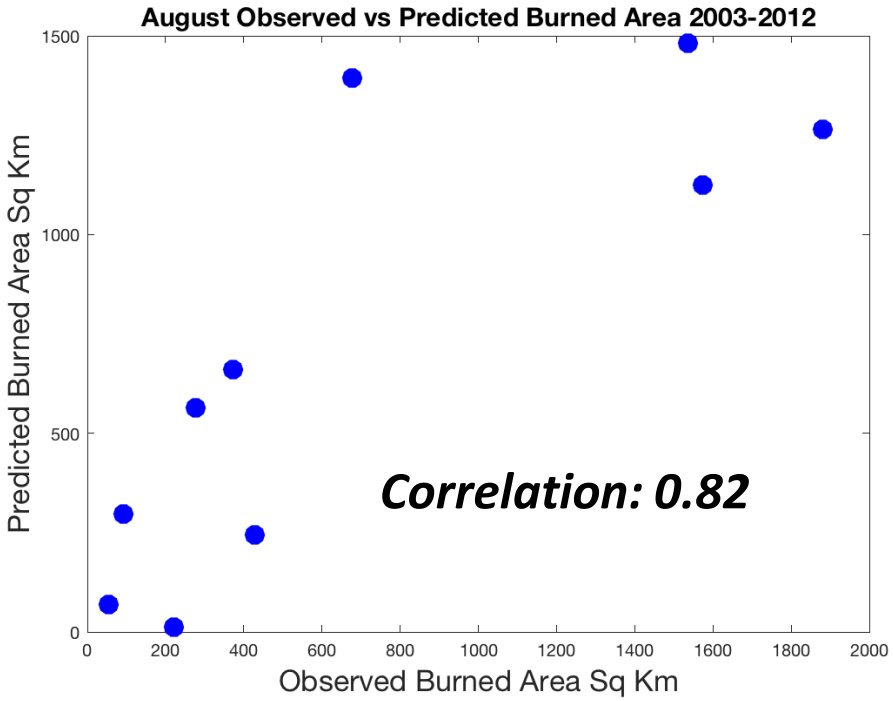
- Best Combination:
1-month lead VPD and 3-month lead SM

Methodology and Results

Step 3: for each month fire prediction:

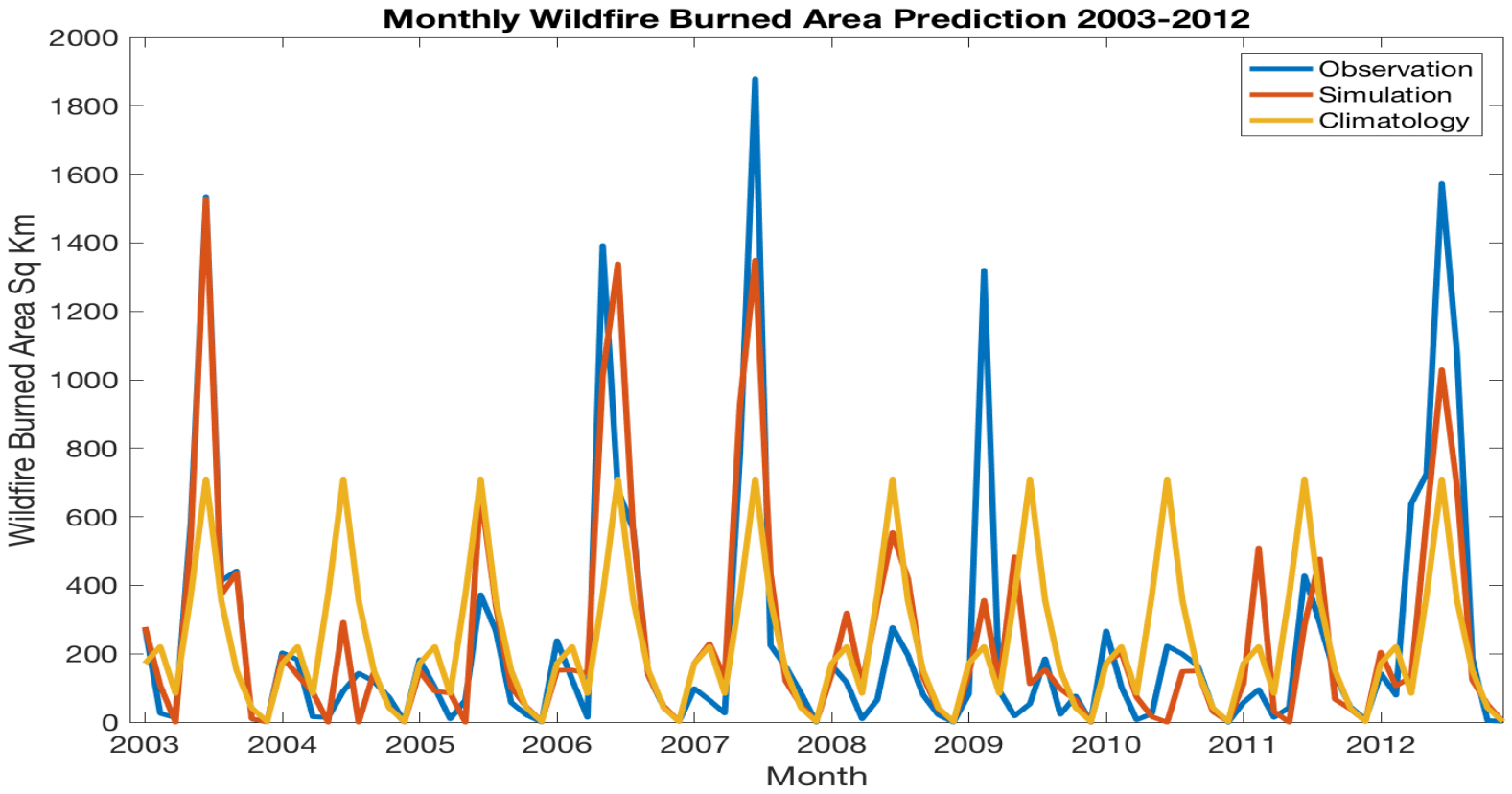
- ❑ if Nash-Sutcliffe > 0 ⟹ Use the model
- ❑ if Nash-Sutcliffe < 0 ⟹ Use climatology

Model Results:



August observed vs predicted fire burned area

Results



Time series of Observed, Predicted and Climatology 2003-2012

Conclusion

- We built a monthly fire burned area prediction model for northern Rockies based on soil moisture and vapor pressure deficit input.
- The model is based on linear regression technique
- The results show that the model can predict fire burned area with relatively small margin of error. The model strength is in detecting interannual variability