**Gatlinburg & Beatty Wildfires**

*Evaluating the Role of Soil Moisture in Determining Vegetation Health, Fuel Loads, and Wildfires in the Gatlinburg and Beatty Wildfires*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The NASA DEVELOP team evaluated the role of soil moisture in determining vegetation health, fuel loads, and wildfires using NASA Earth observations. Partnering with the Desert Research Institute’s Western Regional Climate Center (WRCC), the National Oceanic and Atmospheric Administration (NOAA)'s National Integrated Drought Information System (NIDIS), the North Carolina State Climate Office, and Oklahoma State University, the project determined correlations between fuel load and antecedent soil moisture conditions prior to the Chimney Tops 2 and Bootleg Fires to inform future fire and drought monitoring decisions.

***Abstract:***

Wildfire potential monitoring, which is increasingly vital under climate change-induced droughts, could be improved by incorporating remotely-sensed soil moisture data. To better understand the connections between soil moisture and vegetation health, stakeholders are interested in using soil moisture data in the development of fire-related indices. NASA DEVELOP partnered with the Desert Research Institute’s Western Regional Climate Center (WRCC), NOAA’s National Integrated Drought Information System (NIDIS), the North Carolina State Climate Office, and Oklahoma State University to evaluate how measures of remotely-sensed standardized soil moisture compare to vegetation health and fire fuel indices in a case study of two fire events: the 2016 Chimney Tops 2 Fire near Gatlinburg, Tennessee and the 2021 Bootleg Fire near Beatty, Oregon. The team visualized vegetation change six months prior to each event using spectral vegetation indices observed by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA’s Terra satellite and the Keetch-Byram Drought Index (KBDI). These visualizations were compared to soil moisture data from European Space Agency's (ESA) Climate Change Initiative Soil Moisture (CCI SM) project, collected in part by the Soil Moisture Active Passive (SMAP) satellite. Overall, period of record percentiles and fraction of available water standardizations correlated more strongly with fuel load and vegetation indices, indicating their utility for fire potential monitoring. Soil moisture conditions remained exceptionally dry for several months before the Chimney Tops 2 Fire whereas drought conditions only intensified immediately prior to the Bootleg Fire. This indicates greater sensitivity to drought conditions under Western fire regimes. These findings will inform partners’ monitoring of wildfire potential in both regions and develop early warning systems.

***Key Terms:***

soil moisture, drought, wildfire management, remote sensing, KDBI, MODIS, NDVI, EVI

***National Application Area Addressed:*** Wildfires

***Study Location:*** Gatlinburg, TN; Beatty, OR

***Study Period:*** May 2016 – November 2016; January 2021 – July 2021

***Community Concerns:***

* Fire damage threatens national forests, biodiversity, and historic ecosystems.
* Wildfires bring increased risks of loss of life, air quality concerns, and property damage both during and following their lifespan.
* Historically, Indigenous communities are disproportionately impacted by drought conditions. Wildfires compromise protected land, cultural sites, and resources.

***Project Objectives:***

* Produce fuel load maps and a spatially-averaged time-series utilizing vegetation indices and KBDI
* Analyze soil moisture conditions preceding both fire events across three standardization approaches
* Assess the relationship between vegetation health, soil moisture conditions, and fuel load for correlations with fuel buildup six months prior to both fire events

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Desert Research Institute, Western Regional Climate Center** | Dr. Timothy Brown, Director | End User |
| **NOAA, National Integrated Drought Information System** | Marina Skumanich, Program Specialist for the National Coordinated Soil Moisture Monitoring Network; Britt Parker, Regional Drought Information Coordinator Pacific Northwest Region | End User |
| **North Carolina State Climate Office** | Dr. Sheila Saia, Associate Director; Corey Davis, Assistant State Climatologist | End User |
| **Oklahoma State University** | Dr. Tyson Ochsner, Professor of Plant & Soil Sciences | Collaborator |

***Decision-Making Practices & Policies:***

The North Carolina State Climate Office develops and maintains the Fire Weather Intelligence Portal, a tool for monitoring weather and fire risk conditions in the Southeast United States used by foresters and land managers to plan prescribed burns and track wildfire danger. Similarly, the WRCC develops products for wildfire management by providing drought information for the western United States. In partnership with the WRCC, NIDIS works with decision makers who monitor and manage drought to assist their access to information and identify gaps in information access that NIDIS can address. As part of their work, NIDIS is leading an effort to establish a National Coordinated Soil Moisture Monitoring Network to support improved early hazard warning systems and reduce risks from drought and wildfire by combining *in situ*, satellite data, and modeled products.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Terra MODIS** | Surface reflectance, Normalized Difference Vegetation Index (NDVI); Enhanced Vegetation Index (EVI) | MODIS Terra spectral indices were used to calculate vegetation health, which was then compared to standardized measurements of soil moisture conditions. |
| **SMAP** | Soil moisture | SMAP soil moisture data, within the European Space Agency Climate Change Initiative Soil Moisture (ESA CCI SM) dataset, was used to calculate antecedent soil moisture conditions preceding the two fire events utilizing three standardization approaches. |

***Ancillary Datasets:***

* European Space Agency Climate Change Initiative Soil Moisture Version v07.1 (ESA CCI SM) – Calculate antecedent soil moisture conditions six months prior to the fire events using three standardization approaches: interannual standardized soil moisture, period of record standardized soil moisture, fraction of available water. These methods are based on soil property, and these metrics were compared to measures of vegetation health and fire fuel indices.
* United States Forest Service (USFS) Wildland Fire Assessment System (WFAS) Keetch Byram Drought Index (KDBI) – Compare and correlate with antecedent moisture conditions six months prior to the fire events

***Software & Scripting:***

* RStudio 4.2 – Fuel load maps and spatially averaged time series, antecedent moisture conditions analysis, and fuel load and antecedent moisture comparison
* GEE JavaScript API – MODIS Terra NDVI and EVI animations

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Fuel Load Maps, Vegetation Time Series Animations, and Spatially Averaged Time Series** | Terra MODIS | These animated maps and time series will show partners how wildfire potential in the six months preceding fire events is captured by traditional fuel indices and vegetation health metrics. As such, these analyses will also demonstrate the differences and limitations of individual fuel load and vegetation health metrics in monitoring fire potential. | II |
| **Antecedent Moisture Conditions Analyses** | SMAP | These analyses will demonstrate soil moisture behavior prior to fire events, illustrate the differences among various standardization approaches, and inform the selection of future fire monitoring methods. | II |
| **Fuel Load and Antecedent Moisture Comparison** | Terra MODIS, SMAP | The correlations between spatially averaged time series of fuel load, vegetation health, and soil moisture conditions will illustrate which indices best indicate moisture conditions. This will support partners in their decision making of what metrics have the most potential in aiding fire monitoring efforts. | N/A |

***Product Benefit to End User:***

Although this project’s partner organizations regularly monitor wildfire potential across the nation, soil moisture observations are not traditionally used in fire-related indices. Through the analyzation of vegetation health, fuel load, and antecedent soil moisture conditions, the team will illustrate changes in their behavior prior to both wildfire events. Correlations found within the scope of this project this will allow the NC State Climate Office, the WRCC, and NIDIS to better understand how soil moisture behaves in areas of wildfire risk and how measurements of soil moisture could improve monitoring efforts.

**References**

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