**Southern Idaho Health & Air Quality**

*Monitoring Atmospheric Mixing Heights Post-Wildfire Through the Use of NASA Earth Observations*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Smoke from wildfires has negative impacts on human and environmental health. However, current methods to evaluate and predict smoke pollution are under-researched. This project created a software script to be used as a tool for monitoring smoke plumes using wildfires in and around the southern Idaho region. Specifically, this tool measures mixing heights calculated from satellite imagery during large wildland fire events. The partners included NOAA’s National Weather Service, National Park Service, & Bureau of Land Management. The team used CALIPSO CALIOP, Suomi NPP VIIRS, and Terra and Aqua MODIS data to track aerosol content and movement throughout the atmosphere.

***Abstract:***

Wildfire smoke has long-lasting impacts on public and environmental health. Currently, agencies that monitor smoke base their decisions on an analysis of how fires burn, the direction the smoke moves from the fire source, and unverified estimates of mixing height. Mixing heights describe the maximum altitude to which a smoke plume rises. Satellite imagery provides more continuous and accurate coverage of mixing heights than current *in situ* methods. Thus, the team developed a software tool that processes and extracts mixing height observations from Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Vertical Feature Mask granules. The team partnered with the National Oceanic and Atmospheric Administration’s National Weather Service, the Bureau of Land Management’s National Interagency Fire Center, and the National Park Service’s Fire Management Program Center to analyze historic fire events in southern Idaho. To do so, they used Suomi National Polar-orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS), and Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) to verify where a CALIPSO pass intersects thermal anomalies and smoke plumes. The software extracts features of relevance from the hdf file of each CALIPSO transect to locate layers of continuous aerosols. The maximum altitude at which the aerosol ends is recorded as the mixing height, along with a matching latitude and longitude. The satellite-derived values can be used to validate past mixing height predictions and evaluate the accuracy and systematic bias of different estimation methods. These results may allow agencies to make better comparisons and subsequent smoke pollution management, prevention, and public health decisions if the spatial and temporal differences between predictions and observations can be resolved.

***Key Terms:***

Air quality, wildfire smoke, smoke pollution, mixing height prediction, public health, aerosol dispersion, Idaho

***National Application Area Addressed:*** Health & Air Quality

***Study Location:*** ID

***Study Period:*** August 2013 – August 2020

***Community Concerns:***

* As of 2019, Idaho was ranked in the top five most wildfire-prone states in the USA, and fire intensity and frequency are projected to increase in the next ten years.
* Prescribed burns, which help reduce wildfire risk, are often prohibited due to potential smoke hazard.
* Currently, agencies can not accurately predict or measure the movement and dispersal of wildfire smoke plumes to warn the public of air quality hazards.
* The National Weather Service Fire Weather Program has not determined a national standard for calculating mixing heights because there is little to no validation of the accuracy of different mixing height estimation models.
* A lack of research in this area results in inconsistencies in smoke forecasting between agencies and across state boundaries.

***Project Objectives:***

* Use CALIPSO Lidar data to calculate observed mixing heights of historic wildfire events
* Compare observed data with mixing height estimation from different prediction methods
* Provide project partners with a tool that automates the process of estimating mixing heights from CALIPSO data for future wildfire events

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **NOAA, National Weather Service** | Heath Hockenberry, Fire Weather  Program Manager; Robyn Heffernan,  Predictive Services Meteorologist | End User | No |
| **National Park Service, Fire Management Program Center** | Mark Fitch, Smoke Management  Specialist | End User | No |
| **Bureau of Land Management,**  **National Interagency Fire Center** | Dave Mueller, Hazardous Fuels  Reduction Program | End User | No |

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

The project end users currently make smoke pollution decisions based on an analysis of how fires burn and the direction the smoke takes from the fire source. Atmospheric and smoke variables such as wind speed, humidity, and aerosol concentration are acquired from ground-based weather stations, where the data are then interpolated to make decisions regarding public health warning systems and fire management based on aerosol dispersion. One of the main obstacles that the end users face is quantitatively reliable and consistent mixing-height prediction methods. The partners’ goal is to validate past mixing height predictions during wildfires to see if their predictions from *in situ* measurement sites are accurate. Additionally, the partners are looking for other observational techniques to refine their mixing height estimation and improve smoke pollution warnings and public health decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **CALIPSO CALIOP** | LiDAR Vertical Feature Mask V 4-20 | LiDAR data were used to analyze levels of smoke-related aerosols in the atmosphere, to determine mixing heights. |
| **Terra MODIS** | Deep Blue Aerosol Optical Depth | MODIS data were used to analyze levels of smoke-  related aerosols in the atmosphere that intersect with a CALIPSO pass. |
| **Aqua MODIS** | Deep Blue Aerosol Optical Depth | MODIS data were used to analyze levels of smoke-  related aerosols in the atmosphere that intersect with a CALIPSO pass. |
| **Suomi NPP VIIRS** | Thermal Anomalies | VIIRS data were used to display fires and thermal anomalies that intersected with a CALIPSO pass. |

***Ancillary Datasets:***

* Historic Fires Database (HFD) from Idaho State University GIS Trec Center – Contains over 50,000 documented wildfires from 1950-2020 and was used to map burn scars of fires during the study period
* Atmospheric Sounding Profiles BUFKIT Map from the National Weather Service – Contains location of satellite soundings that was used to determine the spatial and temporal difference between mixing height observations and mixing height predictions

***Modeling:***

* North American Mesoscale Forecast Model (NAM) from National Centers for Environmental Prediction – Used to generate soundings used in mixing height estimations (POC: Larry Van Buron)
* Holzworth Mixing Height Estimation from George Holzworth – Used to estimate mixing heights (POC: Matt Fearon)
* Stull Mixing Height Estimation from Roland Stull – Used to estimate mixing heights (POC: Matt Fearon)

***Software & Scripting:***

* Python 3.8 – Extracting and plotting satellite imagery
* ArcGIS Pro 2.6.3 – Plotting satellite imagery to verify partners’ prediction models

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Mixing Height Observation Tool** | CALIPSO CALIOP  Terra MODIS  Aqua MODIS | This software tool will allow project partners to generate mixing height observations that can be compared to mixing height predictions. | III |
| **CALIPSO Observation Location and Sounding Distribution Maps** | CALIPSO CALIOP  Terra MODIS  Aqua MODIS | These static maps provide partners with a visual representation of spatial differences between mixing height observations and soundings that can be used to make predictions during the study period. | N/A |

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

These products will give the partners observations that can be used to validate methods for their current models of smoke prediction and allow them to better allocate resources related to smoke pollution in the future. Given that there is very little research examining the dispersion of aerosols in the atmosphere, this project will give our partners a better understanding of the mixing height of smoke from wildfire events. The techniques developed by the team will provide end users with better mixing height estimations which will improve smoke pollution warnings and decisions regarding public health. This improved knowledge will also influence go/no-go calls for controlled or prescribed burns.

***Project Continuation Plan:***

The project partners are interested in exploring another term with data and a validation methodology based on the outcome of this project. This study provided insight into smoke behavior in a dry climate regime but cannot be applied equally across the United States without further research, due to varying climate regimes and fuel types. The continuation project will explore mixing height estimation in both wet and dry climate regimes. This study did not successfully validate mixing height prediction based on fires that have occurred in Idaho over the past 9 years because the team did not have enough data to back-calculate mixing height predictions. Future work will pursue validation and will determine the threshold values for spatial and temporal discrepancies between observed and predicted mixing heights.

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