**Southern Idaho Health & Air Quality II**

*Evaluating Atmospheric Mixing Height Estimations in the Western United States*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Wildfire smoke negatively impacts human health. Accurate knowledge of atmospheric mixing heights is critical in determining surface-level air quality; however, there is significant uncertainty in current mixing height estimations as well as inconsistencies in methods across public agencies. The objective of this project was to increase the partners’ confidence in their mixing height estimation techniques, which inform air quality predictions and prescribed burning decisions. To that end, this project provided a statistical analysis of mixing height estimations derived from different methods, as well as a toolbox for validating estimation methods with Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite data.

***Abstract:***

Wildfires in the western United States have caused immense infrastructure damage and loss of human life in recent years. Wildfire smoke, which travels far from its original source, is also harmful to human health. Mixing height, which acts as a lid and prevents smoke from rising above a certain altitude in the lower troposphere, is a critical input in smoke dispersion and air quality models used by agencies that monitor wildfires. These models, coupled with forecaster expertise, are also used to decide when it is safe to execute a prescribed burn. The DEVELOP ID team partnered with the National Weather Service (NWS) Fire Weather Program, Bureau of Land Management (BLM), National Interagency Fire Center (NIFC), and National Park Service (NPS) Fire Management Program Center (FMPC) to help improve reliability and confidence in mixing height estimations, and therefore the burn prescription decision-making process. To that end, the team developed a toolbox for measuring smoke-related aerosol mixing heights using Cloud-Aerosol LiDAR and Infrared Pathfinder Satellite Observations (CALIPSO) Vertical Feature Mask granules. CALIPSO mixing heights and NWS estimations covaried significantly and positively. However, substantial disagreement between the methods stymied the team’s attempts to quantify systematic bias in a meaningful way. The relative error between the methods was especially large at low mixing heights, which suggests that this method of validation may only be suitable at higher altitudes.

***Key Terms:***

Wildfires, smoke pollution, mixing height, aerosol dispersion, CALIPSO, remote sensing, Western US

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

***Study Location:*** Western United States (AZ, CA, CO, ID, MT, NM, OR, NV, UT, WA, WY)

***Study Period:*** 2006 – 2020 (July-September)

***Community Concerns:***

* Wildfire frequency and intensity in the western United States have continually increased over the past 60 years, with 2020 breaking historic records in both total number of fires and acreage burned.
* Prescribed burns, which help reduce wildfire risk, are often vetoed due to potential smoke hazards.
* Accurate mixing height estimations are needed to warn the public of air quality hazards and inform prescribed burn decisions.
* The National Weather Service Fire Weather Program has not determined a national standard for calculating mixing heights, which reduces certainty in air quality forecasts.

***Project Objectives:***

* Automate the Python tool, Automated Satellite Mixing Height Observations and Known Remote Estimations (A-SMOKRE) to compute mixing height estimations for historic smoke plume events from CALIPSO CALIOP VFM data
* Expand study area from Southern Idaho to the entire Western United States and increase sample size to include 200-300 long-lived historic wildfires to increase the probability of a CALIPSO pass intersecting the smoke plume itself in order to derive direct mixing height observations
* Develop a Python tool to estimate mixing height for historic smoke plume events from Terra MODIS Atmospheric Profile data
* Compare CALIPSO mixing height observations and NWS model-based estimations qualitatively and quantitatively

***Previous Term***

2020 Fall (ID) – Southern Idaho Health & Air Quality

**Partner Overview**

***Partner Organizations:***

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

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

National Weather Service forecasters currently use models dependent on environmental variables that can be measured on the ground, such as wind speed, humidity, and aerosol concentration, to estimate mixing height. These estimates inform the partner organizations’ decisions regarding public health warning systems and prescribed burning based on smoke dispersion. The partners’ goal is to evaluate past mixing height predictions during wildfires to see if National Weather Service forecaster-refined model estimations are accurate, because there is uncertainty and inconsistency in these estimations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **CALIPSO CALIOP** | LiDAR Vertical Feature Mask (VFM) | Feature classifications used to determine levels of smoke-related aerosols in the atmosphere and calculate mixing height. |
| **Terra MODIS** | Atmospheric Profiles; Corrected Reflectance (True Color) | Vertical water vapor mixing ratio profiles used to estimate mixing height. True color imagery was used to identify plume intersection with CALIPSO passes. |
| **Aqua MODIS** | Corrected Reflectance (True Color) | True color imagery was used to identify plume intersection with CALIPSO passes. |
| **Suomi NPP VIIRS** | Thermal anomalies | Locate fires near CALIPSO passes. |

***Ancillary Datasets:***

* Historic Fires Database (HFD) from Idaho State University GIS Training and Research Center (TReC) – contains over 50,000 documented wildfires from 1950-present and was used to map burn scars of fires during the study period
* Archive of National Weather Service Forecasts from the Iowa Environmental Mesonet – contains archive of the National Weather Service Text Products including Fire Weather Forecasts and Spot Forecasts which contain forecasted mixing height values
* CALIPSO CIMSS Surface Attached Aerosol Layer product from the University of Wisconsin – a proxy for mixing layer height, which is calculated using a wavelet covariance transform applied to the CALIPSO Lidar backscatter profiles

***Software & Scripting:***

* Python 3.9.1 – Developing tools for deriving mixing heights from CALIPSO and MODIS data, statistical analysis
* Esri ArcGIS Pro 2.7.2 – Geospatial analysis and visualization for site selection, generating figures and maps, website image

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Mixing Height Estimation Toolbox (MHEST)** | CALIPSO CALIOP, Terra MODIS | This toolbox contains python scripts that allows project partners to generate estimations of mixing height from input CALIPSO Vertical Feature Mask and MODIS Atmospheric Profile data. Additionally, it contains scripts related to the data processing in the mixing height validation assessment and the automated collection of mixing height forecasts from the Iowa Environmental Database National Weather Service Text Product archive. | IV |
| **Mixing Height Validation Assessment** | CALIPSO CALIOP, Terra MODIS | This validation assessment is a descriptive comparative analysis of mixing height observations derived from A-SMOKRE with NWS historical mixing height estimations. This will provide the partners with valuable information on the accuracy of their current techniques which may be used to refine their methodologies and improve air quality forecasts for fire management decisions. | N/A |
| **StoryMap** | CALIPSO CALIOP, Terra & Aqua MODIS, Suomi NPP VIIRS | The StoryMap provides a summary of this project's results, as well as information for the public describing the importance of accurate mixing heights in determining air quality and the safety of prescribed burns. | N/A |

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

Accurate estimations of boundary layer mixing heights are critically important in smoke prediction models used by the partners. The A-SMOKRE tool will provide direct observations of historic smoke plume mixing heights to validate the project partners’ current estimation models. The partners are not seeking a new tool to estimate real-time mixing heights, and this is not possible given the six-month delay between CALIPSO passes and CALIPSO VFM data availability. In conjunction with our report on the accuracies of the partners’ methods, these products will provide the end users with additional information on mixing height estimations that they can use to improve air quality forecasts and go/no-go decisions for prescribed burns.

**References**

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