FINAL REPORT

University: South Dakota School of Mines and Technology

Name of University Researcher Preparing Report: Darren R. Clabo

NWS Office: NOAA Storm Prediction Center

Name of NWS Researcher Preparing Report: Patrick Marsh

Type of Project (Partners or Cooperative): Partners

Project Title: Establishing a relationship between mixing height and wildfire growth: An observational study

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Section 1: Summary Project Objectives

There were two primary objectives of this one-year project: 1) to establish a 00 UTC mixing height climatology for each of the National Weather Service's radiosonde locations and 2) determine if a relationship exists between climatologically high mixing heights and large wildland fire growth.

Section 2: Project Accomplishments and Findings

To accomplish the first objective of this project, a mixing height climatology was established for the contiguous United States. The climatology was created from daily 00 UTC radiosonde for each of the NWS-sponsored radiosonde launching sites from 1975 – 2019 (excluding February 29 during leap years). Three different methods were used to calculate the mixing height to build the climatology at each radiosonde location: 1) the Stull method (Stull 1988), 2) a modified Stull method where 1 K was added to the surface parcel's virtual potential temperature, and 3) and an additional modified Stull method where the surface parcel's virtual potential temperature was set to the highest virtual potential temperature found in the lowest 500 meters to the surface. The latter two methods were used to avoid issues revolving around the development of a surface-based inversion at 00 UTC, which is late in the day for most US locations especially during the cool season. A test webpage for the climatology has been developed by the Storm Prediction Center (SPC) and it is anticipated that the full climatology from this study will be incorporated into their operational Sounding Climatology Webpage. A 12 UTC radiosonde climatology, built in a similar fashion to the 00 UTC climatology, will be completed mid-summer 2021.

Results of the climatology showed that significant variations in mixing heights are observed across the United States. In general, the western half of the US experiences the highest mixing heights while the eastern US experiences the lowest mixing heights throughout the year. Mixing heights were highest during the hottest times of the year and lowest during the winter months. The exception to this trend was coastal southern California where the highest mixing heights were found during the winter months. This pattern may be related to the effect of the southwest monsoon or to the climatology of the coastal marine layer. Percentiles for mixing heights were calculated so that operational meteorologists can easily compare daily mixing heights to the historical mixing heights for their location.

The second objective of this project was to compare the mixing heights observed during periods of large fire growth on ongoing wildfires to the mixing height climatology. We looked to answer the question: *are abnormally high mixing heights found during periods of large wildfire growth?* Six wildfires were studied encompassing prairie wildfires and those in complex terrain as well as both warm and cold season wildfires. Results showed that there was a tendency for fires to grow significantly on days with climatologically high mixing heights (above the 75th percentile). But because of the small samples size, it was difficult to draw definitive conclusions. One primary problem with this study was the lack of wind speed information: strong winds can lead to very large fire growth. A secondary problem was using the 00 UTC radiosonde as there were several cases where significant wind shifts/boundaries passed over the fire location *before* the radiosonde launch. Significant wildfire growth occurred on the afternoon of the associated radiosonde but the 00 UTC radiosonde launch captured a different environment after the primary growth period. Furthermore, the 00 UTC radiosonde launch occurs after peak heating (and in the cold season, well after sunset) and even the modified Stull Method may not accurately capture the day's true mixing height. A natural extension of this project would be to use high-resolution numerical weather prediction systems to estimate the mixing heights at similar times to when the large fire growth was observed to occur during the peak heating of the day.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

The results of this project have been incorporated into a soon-to-be-released update to the SPC Sounding Climatology website (https://www.spc.noaa.gov/soundingclimo). This website is available to all NWS forecasters and fire managers to use as a situational awareness tool to understand current events, and, more importantly, provide impact-based decision support services to partners, in an appropriate historical context. Additionally, by providing data from multiple methods of calculating the mixing height, users can explore the potential implications of these different methods on a seasonal and historical basis.

Section 4: Benefits and Lessons Learned: University Partner Perspective

This project enabled a second-year graduate student to finish a master's thesis while producing an operationally-relevant metric (the mixing height climatology) for the wildland fire community. This inherently benefits the university through increased exposure to the forecasting community and through new relationships built with the scientists at the SPC. The PI is optimistic that a research-to-operations bridge can be built between the two institutions to further increase the research output of the university while simultaneously improving fire weather forecasts.

During the course of this project, it was learned that daily wildfire acreage burned data are incredibly difficult to work with as it is unknown when the fire growth occurred during the day and what types of suppression actions occurred that may have either limited or, in the case of burn-out operations, led to additional unnatural fire growth. Furthermore, late-afternoon 00 UTC radiosondes may sample the environment after significant growth occurred when a new airmass may be in place. These were not fatal flaws in the study, but they did demonstrate the importance of the nuances within the data.

Section 5: Publications and Presentations

Woody, C., 2020: Establishment of a Mixing Height Climatology for Use Toward Predicting Daily Large Fire Potential. Thesis, Program in Atmospheric and Environmental Sciences, South Dakota School of Mines and Technology. 120 pp.

Woody, C. and D. R. Clabo, 2021: Establishment of a Mixing Height Climatology for Use Towards Predicting Daily Large Fire Potential. *13th Fire and Forest Meteorology Symposium*, Virtual Platform, Amer. Meteor. Soc., F004.

Clabo, D. R., and C. Woody, 2021: Establishment of a Mixing Height Climatology Derived from the National Weather Service Rawinsonde Network. *In progress.*

Woody, C., and D. R. Clabo, 2021: Predicting fire behavior potential utilizing a mixing height climatology. *In progress.*

Section 6: Summary of University/Operational Partner Interactions and Roles

Darren R. Clabo, South Dakota School of Mines and Technology (PI): Provided guidance for master's student Christopher Woody during the project. Hosted conference calls with the SPC and Chris Woody to discuss project timeline, objectives, and methodology. Provided edits and reviews of thesis manuscript.

Christopher Woody, South Dakota School of Mines and Technology: Obtained all data for the project and created the mixing height climatology. Researched the wildfire case studies, downloaded wildfire and meteorology data, and created figures for publication(s).

Patrick Marsh, Storm Prediction Center: Provided guidance on SPC's needs for implementation of the mixing height climatology.