Advancing Smoke Management and Wildfire Mitigation through Probability-Based Smoke Analysis

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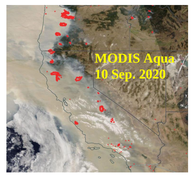
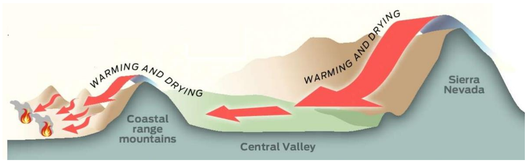
❑ Motivation

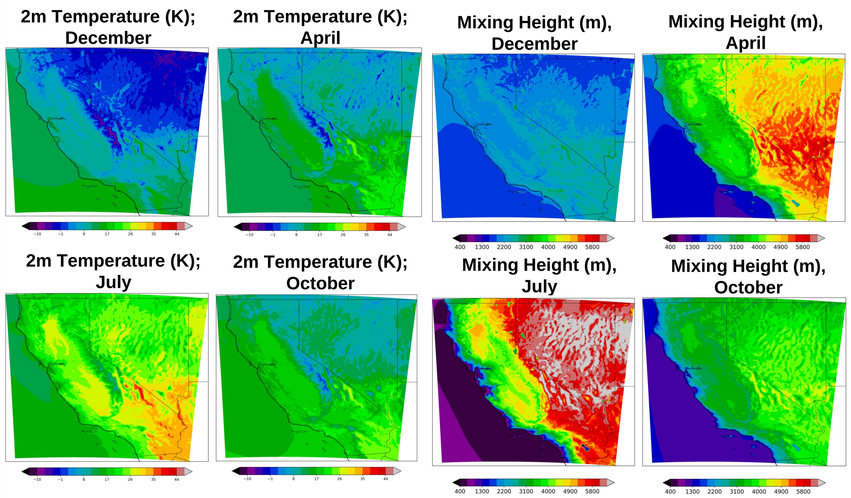
- Large wildfires in the western U.S. are a national concern. To address the urgent need for reducing hazardous fuels and mitigating severe wildfires in the western U.S., particularly in California, fuel treatment activities, including prescribed fires, have emerged as crucial tools.
- However, effective planning and coordination of prescribed fires is essential to minimize the adverse impacts of smoke on downwind air quality.
- Although complex terrain and unexpected gusts favor uncontrollable wildfires or rapid fire spread, high-resolution weather forecasting and climatological data provide valuable insights for avoiding them.
- This study develops a tool that provides valuable insights to support decision-making processes, facilitating improved management of smoke from prescribed fires and ultimately enhancing wildfire mitigation efforts in California's smoke-sensitive areas.





❑ Climatology (2001-2020)

- We utilized 20-year climatological data from California and Nevada Smoke and Air Committee (CANSAC; Brown and Kahyaoglu-Koracin, 2007) products, which are the results of Weather Research and Forecasting (WRF) modeling with a horizontal resolution of 2km and a temporal resolution of 1 hour.
- CANSAC data are by far the finest reanalysis database over a long period of time and are readily available for this project.



❑ Trajectory Analysis

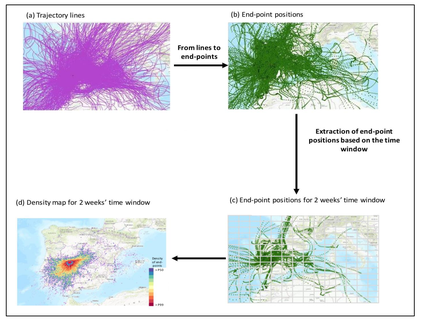
- We use the Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT; Stein et al., 2015) to describe the atmospheric transport, as well as track and forecast the wild and prescribed fire smoke through ensemble air mass trajectory calculations.
- We simulate 72-hour forward trajectories initiated from each of the approximately 190,000 grid cells (over land and shoreline) within the domain for each day in the time period 2001-2020.
- These trajectories are generated four times per day at four different heights, resulting in a substantial number of air mass trajectories. This approach enables us to explore numerous transport and dispersion scenarios.
- We conduct two types of statistical analyses to understand the likelihood and variability of air movement and to identify representative flow patterns:

1. Probability Calculation: For each starting location of trajectories, we calculate the relative frequency of smoke transport to all other locations in the domain.

2. Trajectory Clustering Using Total Spatial Variance

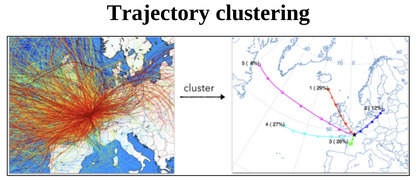
- In addition to forward trajectories, we conduct model simulations and statistical analyses for backward trajectories. This helps us determine the potential source regions for the observed smoke in each grid cell, especially during multiple simultaneous different fires.

Probability calculation



Hernández-Ceballos et al. (2019)

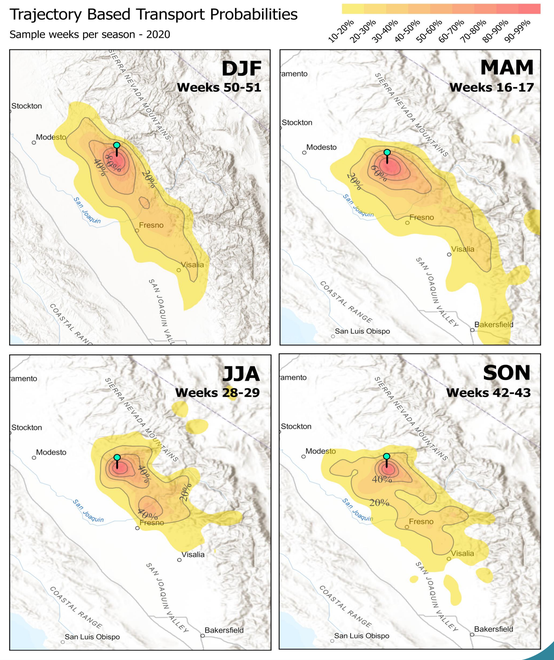
Trajectory clustering



Petit et al. (2017)

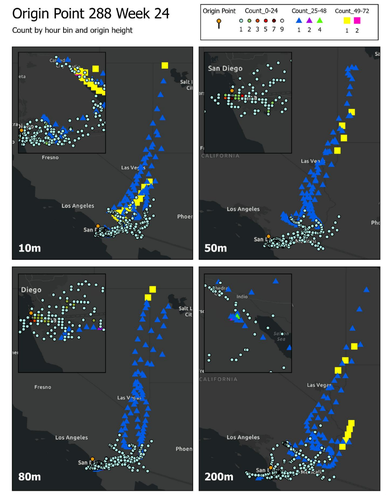
❑ Probability calculation

- First, we extract hourly end-point positions.
- Then we aggregate the subset of end-point positions during our weekly analysis period.
- Next, we generate density maps using box counting.
- We repeat this analysis for monthly, annual, and full climatology time periods.



❑ Trajectory clustering

- We identify trajectory groups with similar spatial patterns and variability, helping to reveal significant airflow pathways.



❑ Highlights

- The methodology incorporates HYSPLIT trajectory modeling fed by 2-km CANSAC-WRF reanalysis products, statistical probability analysis, and clustering techniques.
- The developed tool in this study provides instantaneous results regarding the probability of downwind smoke impact by leveraging a high-resolution reanalysis climatology spanning 20 years, covering the CANSAC domain.
- This provides a comprehensive understanding of air movement likelihood, variability, and potential source regions for smoke.
- The outcomes of this study will be integrated into a user-friendly web interface that enables users to specify a time window and location for a long-term planned prescribed fire project.
- Through this interface, users will have access to instantaneous results displaying the probability of the downwind impact of smoke from both prescribed fires and wildfires.
- This product can also be utilized by air districts for emergency response to wildfires.

Acknowledgment

This study is supported by the California Department of Forestry and Fire Protection (Cal Fire).

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