SmokePath Explorer
A New Smoke Management Tool for California

Virtual Workshop
January 24, 2025

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Desert Research Institute: Farnaz Hosseinpour (Lead-PI), Azimeh Zare Harofteh, Tim Brown, and Naresh Kumar

Acknowledgements

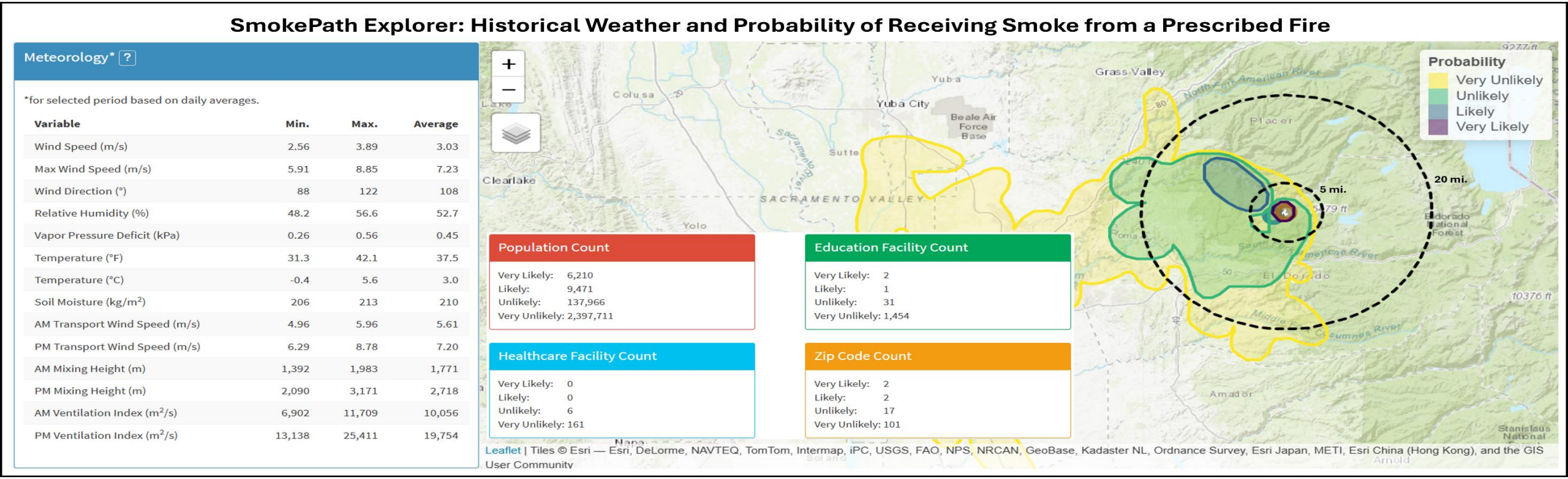
- California Climate Investments
- California Department of Fire and Forestry (CAL FIRE)
- Desert Research Institute (DRI)
- Sonoma Technology
- California and Nevada Air and Smoke Committee (CANSAC)

The Forest Health Research Program is part of California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy, and improving public health and the environment — particularly in disadvantaged communities.

Introduction

- Prescribed fires are one of the most effective tools to reduce hazardous fuels (vegetation).
- The use of prescribed fires to help manage the landscape is expected to significantly increase in the coming years.
- Any vegetation burning emits smoke and harmful air pollutants. However, prescribed fires can minimize smoke impacts on downwind air quality, especially in comparison to uncontrolled wildfires.
- To conduct prescribed fires effectively, land and air quality managers need information and tools to support smoke management.

SmokePath Explorer



- SmokePath Explorer for prescribed fire planning and wildfire response.
- Allows users to specify a time and location for a planned prescribed fire or current wildfire and view fire weather statistics and the probability of downwind smoke impacts.

Workshop Goals

- Provide an overview of SmokePath Explorer
- Demonstrate three case studies based on past prescribed fire projects
- Establish guidance for using the tool
- Equip air and land managers with SmokePath Explorer to:
  - Plan prescribed fires
  - Inform smoke management plans and permits
  - Initiate more timely community communication of potential smoke impacts
  - Inform efforts to assist at-risk populations

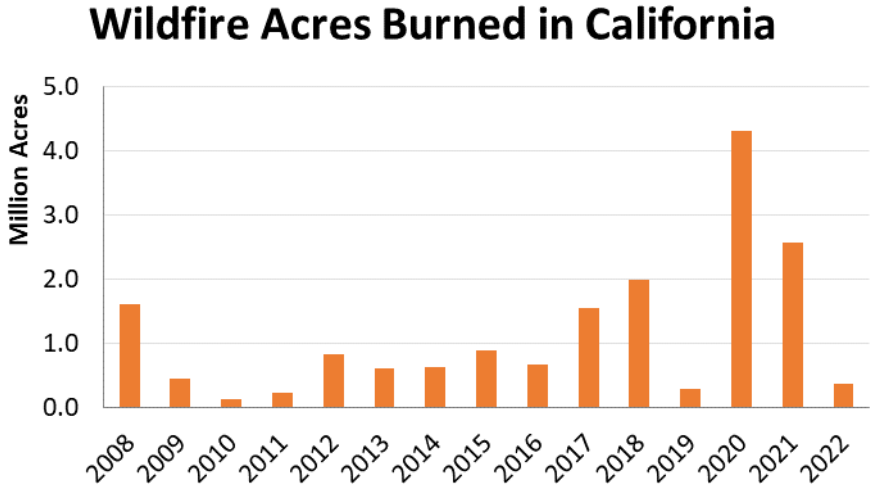
Workshop Overview

- CAL FIRE on expected Use Cases
- General Overview of SmokePath Explorer
- SmokePath Demonstration (focused on three use cases/case studies)
- Q&A (for demos/tools)
- Discussion
- Feedback Survey

SmokePath Explorer Project Overview

Background

- Growing wildfire crisis due to past fire exclusion, climate change, and human footprint expansion.
- Prescribed fire is an effective treatment to reduce fuels (vegetation) and mitigate wildfire risks.
- Statewide plan sets acreage targets of beneficial fires at 400K-500K acres annually by 2025.*
- Smoke management for prescribed fires is needed to minimize smoke impacts on downwind air quality.

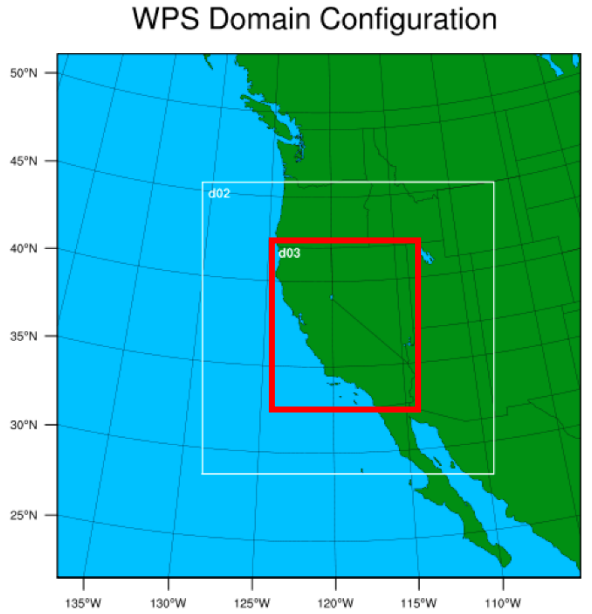


CAL FIRE Statistics

*California Wildfire & Forest Resilience Task Force. (2022). California's Strategic Plan for Expanding the Use of Beneficial Fire.

Methods – Data

- Foundational dataset: CANSAC 20-yr, 2-km, hourly weather reanalysis for 2001-2020 from the Weather Research and Forecasting (WRF) model.
- End-User Input:
  - A short survey on fire weather data and needs was sent to 25 land and air managers in California in March 2023.
  - Priority fire weather metrics identified by nine respondents from local, state, and federal organizations.
- Receptor Data:
  - Education and healthcare facilities point data from Homeland Infrastructure Foundation-Level Data (HIFLD) national dataset.*
  - California ZIP code polygons with population data from the 2020 U.S. Census.



Priority Fire Weather Variables	
Variable	% of Respondents
Relative Humidity	100%
Wind Direction	100%
Wind Speed	100%
Temperature	89%
Mixing Height	67%
Transport Wind	67%
Soil Moisture	56%
Ventilation Index	44%
Vapor Pressure Deficit	33%

*https://hifld-geoplatform.opendata.arcgis.com/

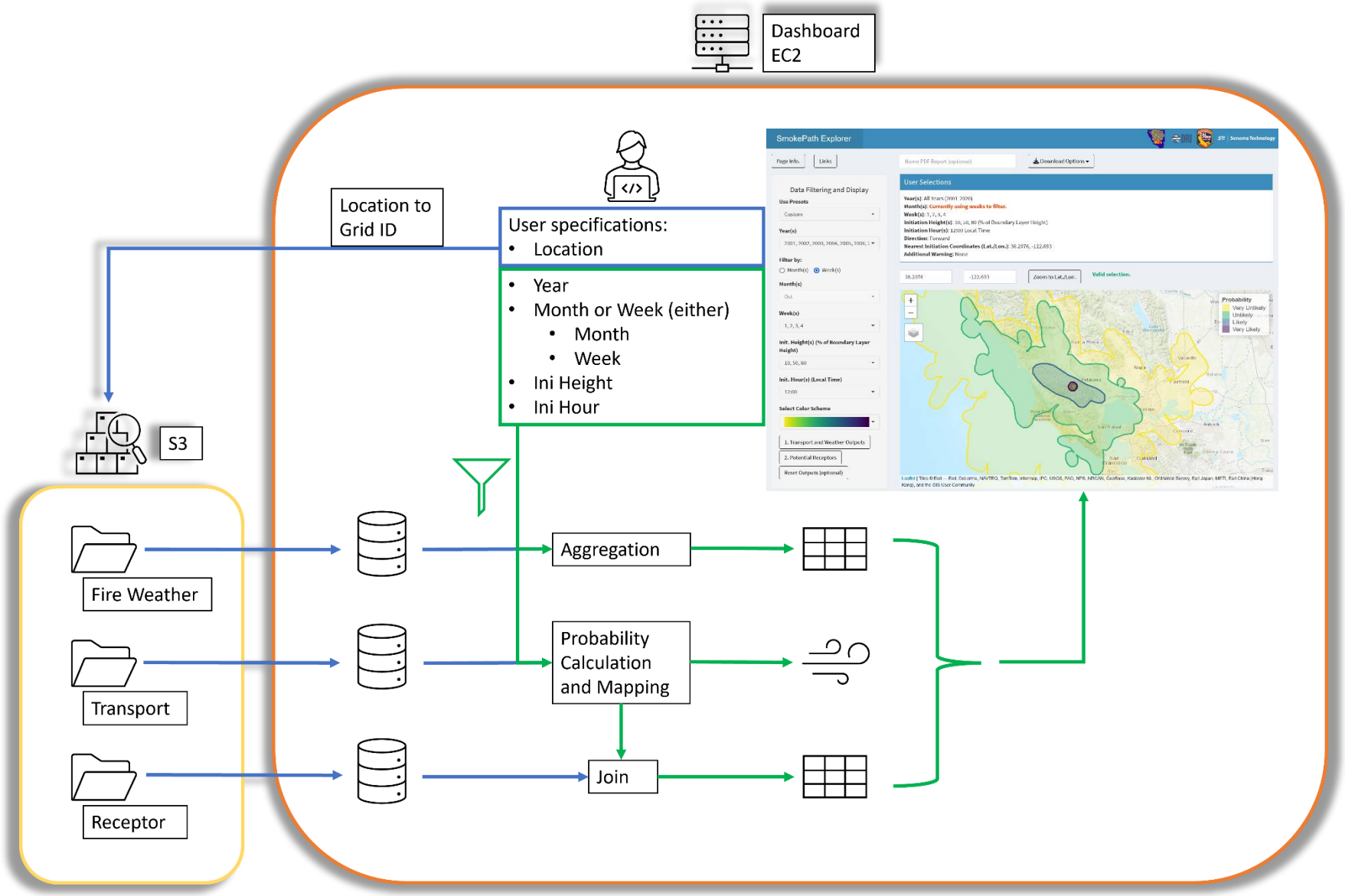
Methods – Transport and Fire Weather

- Transport modeling
  - HYSPLIT trajectory model
  - Every day for 2001-2020
    - Start heights per day (10%, 50%, 80%, and 200% mixing height) (*Plume Rise Indicator)
    - Start times per day (00:00, 6:00, 12:00, and 18:00 hours local time) (*Diurnal Representation)
  - The count of the trajectory points is calculated per case, starting time, and starting height.

1.3 billion HYSPLIT trajectory runs!

- Fire Weather Climatology
  - The daily average values are calculated for fire weather variables from the CANSAC reanalysis 2001-2020.
  - From the 20 years of data, we show the average, maximum, and minimum values.

Methods – Data Dashboard Schema



SmokePath Explorer

Page Info. | Links

Name PDF Report (optional) | Download Options

Data Filtering and Display

Use Presets
Custom

Year(s)
2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019,

Filter by:
(•) Month(s) ( ) Week(s)

Month(s)
Oct

Week(s)
41, 42

Init. Height(s) (% of Boundary Layer Height)
10, 50

Init. Hour(s) (Local Time)
12:00

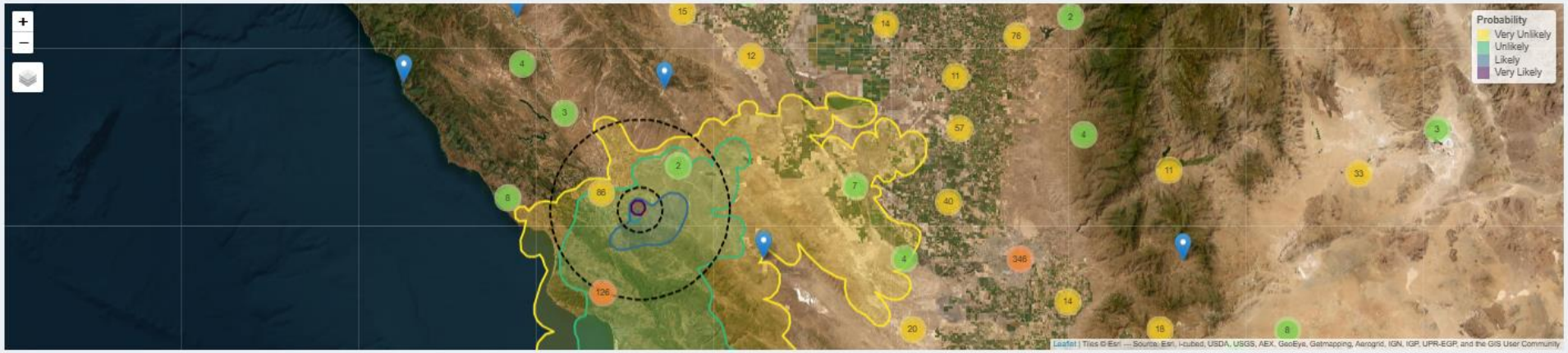
Select Color Scheme

1. Transport and Weather Outputs
2. Potential Receptors
Reset Outputs (optional)

User Selections

Year(s): All Years (2001-2020)
Month(s): Oct
Week(s): Currently using months to filter.
Initiation Height(s): 10, 50 (% of Boundary Layer Height)
Initiation Hour(s): 12:00 Local Time
Direction: Forward
Nearest Initiation Coordinates (Lat./Lon.): 35.5132, -120.527
Additional Warning: None

Zoom to Lat./Lon.



Meteorology* ?

*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	0.54	3.74	1.71
Max Wind Speed (m/s)	2.25	9.27	5.19
Wind Direction (°)	101	336	246
Relative Humidity (%)	15.5	70.6	36.9
Vapor Pressure Deficit (kPa)	0.51	3.09	1.61
Temperature (°F)	53.1	84.1	68.1
Temperature (°C)	11.7	29.0	20.0
Soil Moisture (kg/m²)	54	91	74
AM Transport Wind Speed (m/s)	1.85	7.16	3.87
PM Transport Wind Speed (m/s)	2.73	9.08	4.89
AM Mixing Height (m)	713	2,353	1,341
PM Mixing Height (m)	1,817	5,036	3,213
AM Ventilation Index (m²/s)	1,633	13,389	5,324
PM Ventilation Index (m²/s)	5,975	32,018	15,577

Potential Receptors ?

Population Count

Very Likely: 47,153
Likely: 148,293
Unlikely: 734,015
Very Unlikely: 1,216,233

Education Facility Count

Very Likely: 1
Likely: 4
Unlikely: 442
Very Unlikely: 839

Healthcare Facility Count

Very Likely: 0
Likely: 0
Unlikely: 58
Very Unlikely: 103

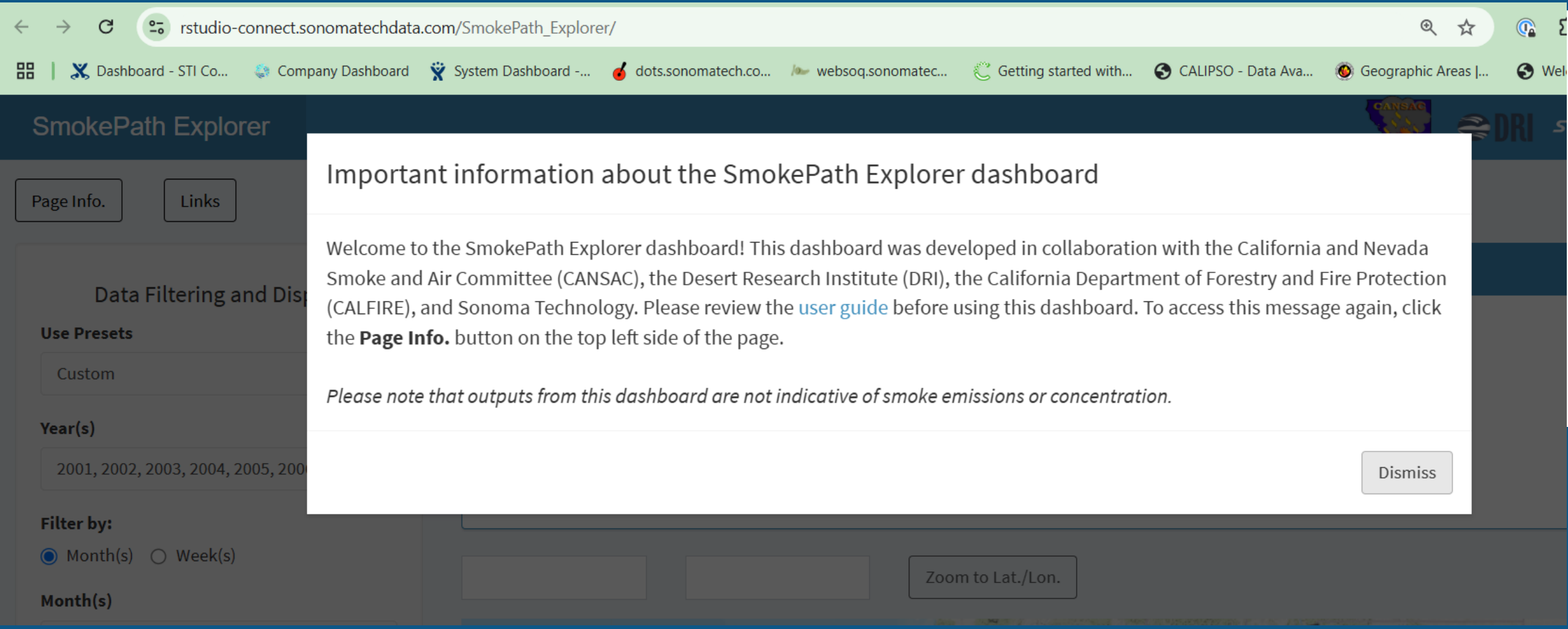
Zip Code Count

Very Likely: 2
Likely: 7
Unlikely: 41
Very Unlikely: 69

Zip Code List

Very Likely: 93432, 93446
Likely: 93465, 93461, 93453, 93422, 93432, 93446, 93117
Unlikely: 93110, 93442, 93109, 93424, 93445, 93454, 93420, 93465, 93461, 93013, 93401, 93436, 93405, 93249, 93410, 93433, 93067, 93402, 93441, 93453, 93427, 93422, 93432, 93434, 93440, 93444, 93446, 93449, 93455, 93458, 93001, 93101, 93103, 93111, 93105, 93108, 93117, 93408, 93407, 93106, 93409
Very Unlikely: 93110, 93239, 93442, 93109, 93224, 93251, 93424, 93445, 93454, 93022, 93066, 93023, 93420, 93429, 93465, 93460, 93461, 93013, 93401, 93436, 93212, 93405, 93437, 93042, 93249, 93410, 93433, 93035, 93067, 93402, 93441, 93453, 93427, 93422, 93430, 93432, 93434, 93440, 93444, 93446, 93449, 93451, 93463, 93455, 93458, 93003, 93001, 93004, 93060, 93101, 93103, 93111, 93204, 93030, 93105, 93108, 93033, 93036, 93041, 93043, 93117, 93201, 93206, 93280, 93254, 93408, 93407, 93106, 93409

SmokePath Explorer: Overview



This tool shows where smoke is likely to go given an emission location. It does not indicate smoke emission or fire size or represent air concentrations.

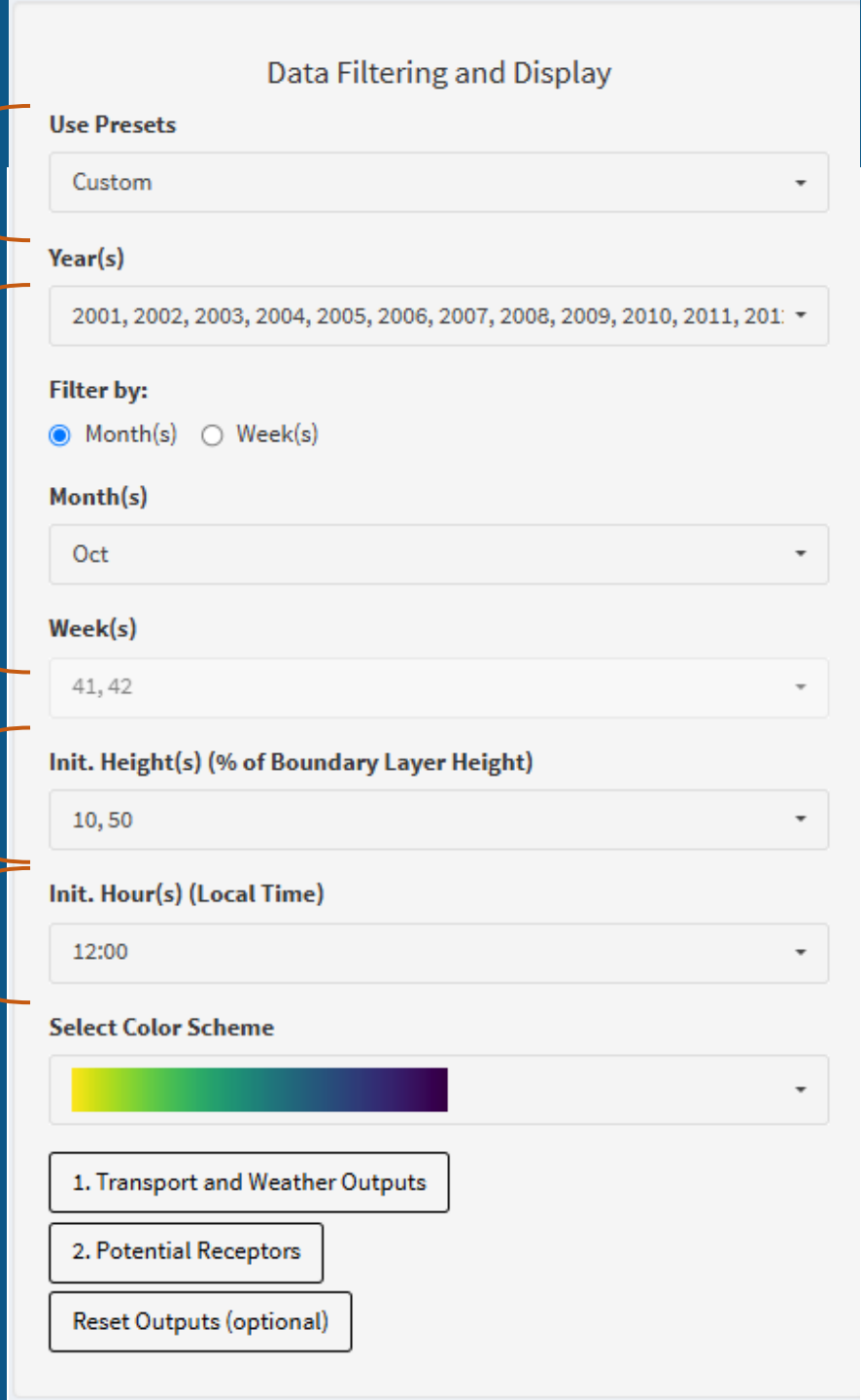
SmokePath Explorer: Overview

Presets:
- Current Week (all years, well-mixed)
- Current Month (all years, well-mixed)

Custom:
- Individual Year or Full Climatology
- Month or Week of Year(s)

- Select initiating height(s) for SmokePath. Multiple selections can be chosen to represent multiple plume injection heights and/or well-mixed boundary layers.
    - •10%: (i.e.: little plume rise; downdraft plume).
    - •50%: (i.e.: moderate plume rise; buoyant plume).
    - •80%: (i.e.: high plume rise; convective plume).
    - •200%: (i.e.: extreme plume rise; deep convective plume).

-Initiating time(s) of day to for the SmokePath. Use all for a full diurnal profile is important.
00:00: nighttime | 06:00: morning | 12:00: afternoon |18:00: evening



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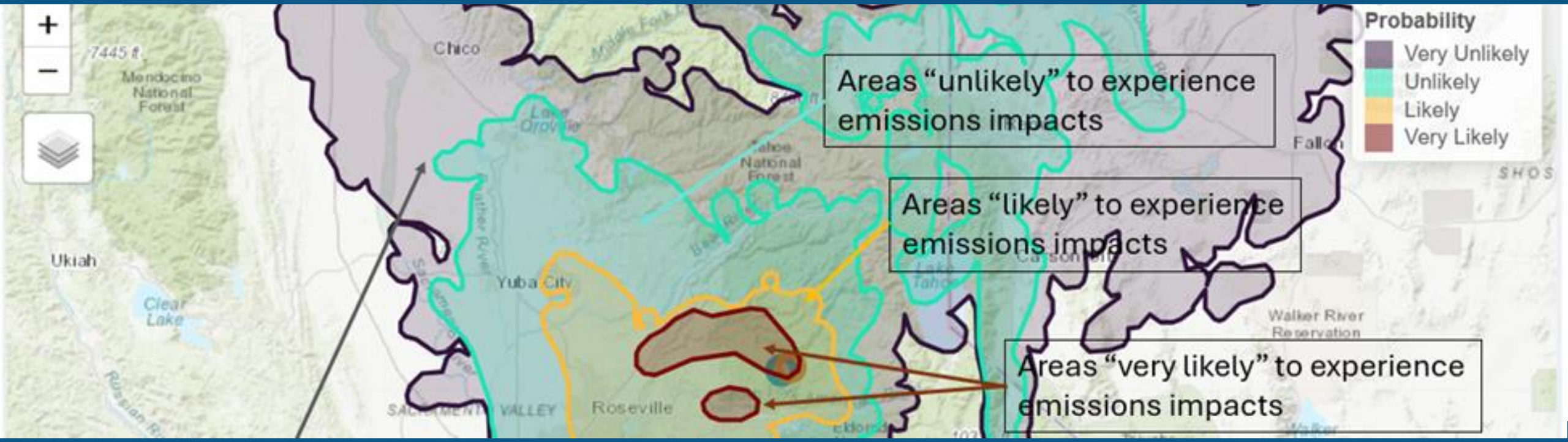

SmokePath Explorer generates (1) a map that shows the probability or likelihood of areas being impacted by smoke from a fire, and (2) meteorological information relevant to fire weather based on daily average values using data from the selected period.

The meteorological data and the comparison of individual years to the 20-yr climatological record can help develop, validate, or compare to the fire prescription.

SmokePath Explorer: Overview

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*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	0.54	3.74	1.71
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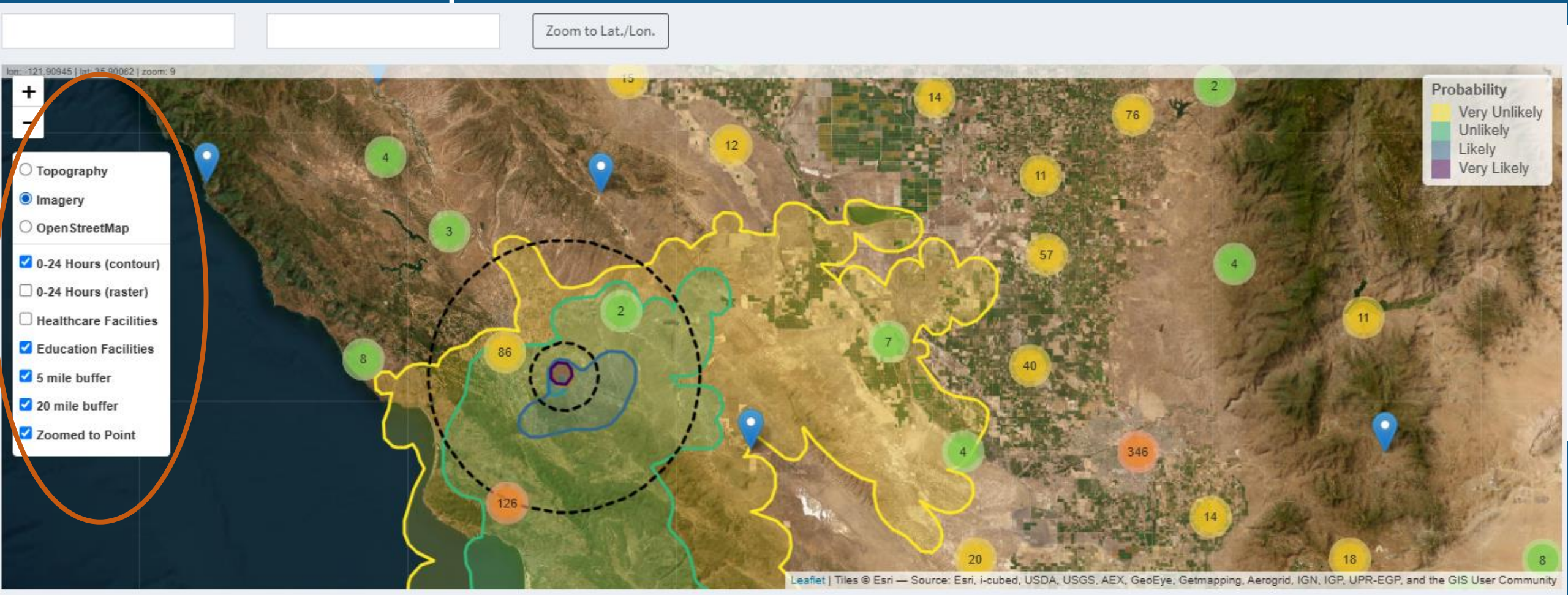
The education receptors include public schools, private schools, childcare centers, colleges, and universities. The healthcare receptors include general medical and surgical hospitals, long-term care hospitals, and elderly care facilities. Population and ZIP codes based on the 2020 Census

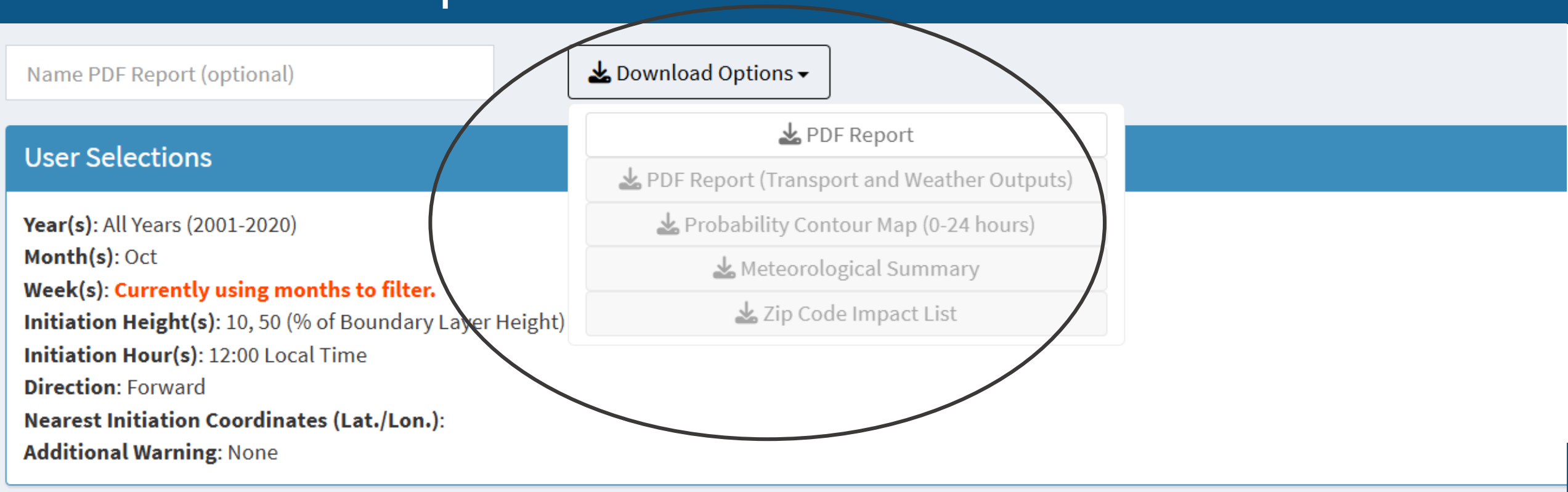
SmokePath Explorer: Overview



The map allows customization of the base-layer (topography, satellite, and roadways). Healthcare and education facilities can also be enabled, zoom to view facility name.

To meet current needs, 5-mile and 20-mile buffer zones can be directly indicated.

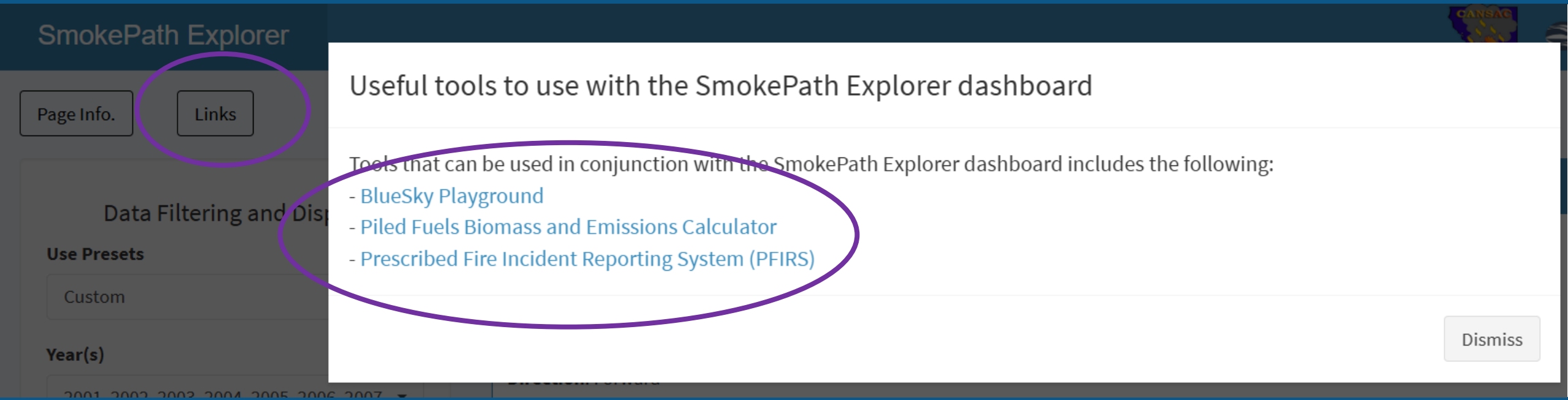
SmokePath Explorer: Overview



The download option allows you to save a copy of the entire report or its pieces in PDF form. This is convenient for comparing different options, team discussions and planning, permitting and smoke management planning.

The ZIP code impact list is a text file (CSV, excel) that can be downloaded and used to expedite notifications and newsletters about upcoming burns.

SmokePath Explorer: Overview



Links are directly available to take you to the next step:
- Week to day-of smoke modeling
- Emission estimates for pile burns and other small fires
- Reporting and tracking (regulatory)

Please let us know if there are additional links that would be useful here!

SmokePath Explorer Demonstration

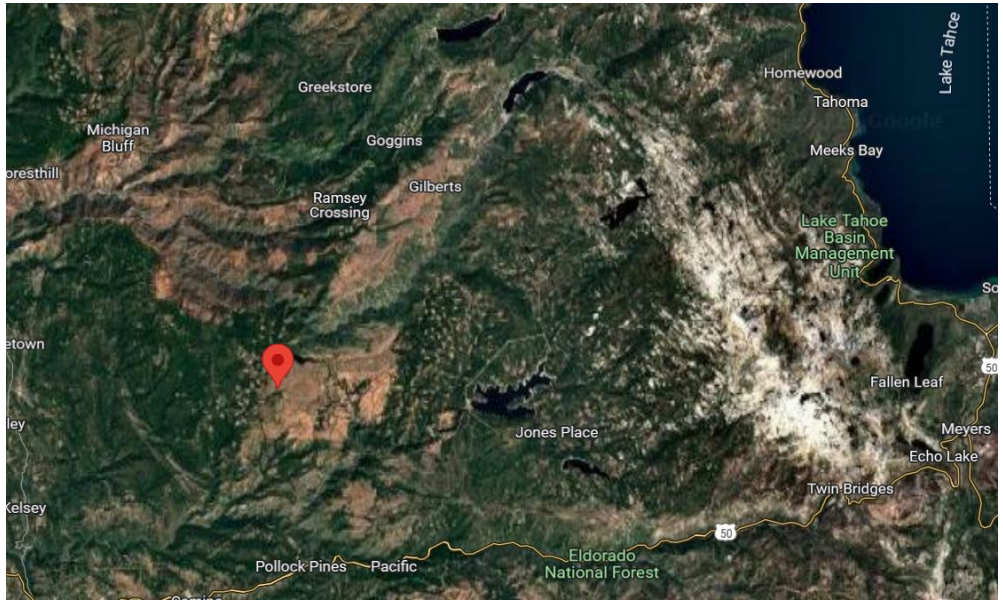
Case Study 1 – The Mountain Prescribed Fire

Objective: Determine likely smoke impacts from the Mountain Prescribed Fire in the Mountain Counties air basin in California.

Area: 16,000 acres

Duration: November 13-24, 2015

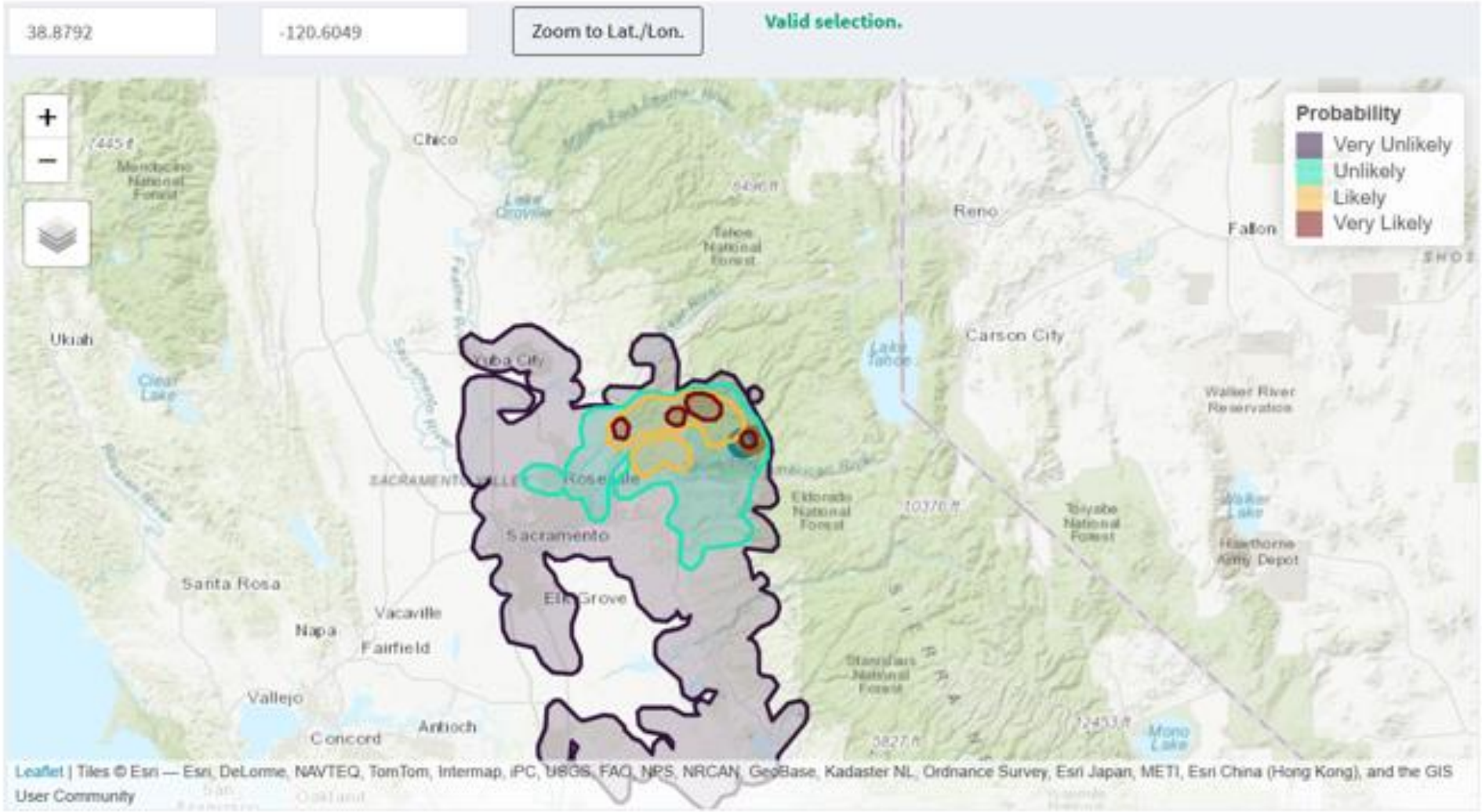
Lat, Lon: 38.8792, -120.6049



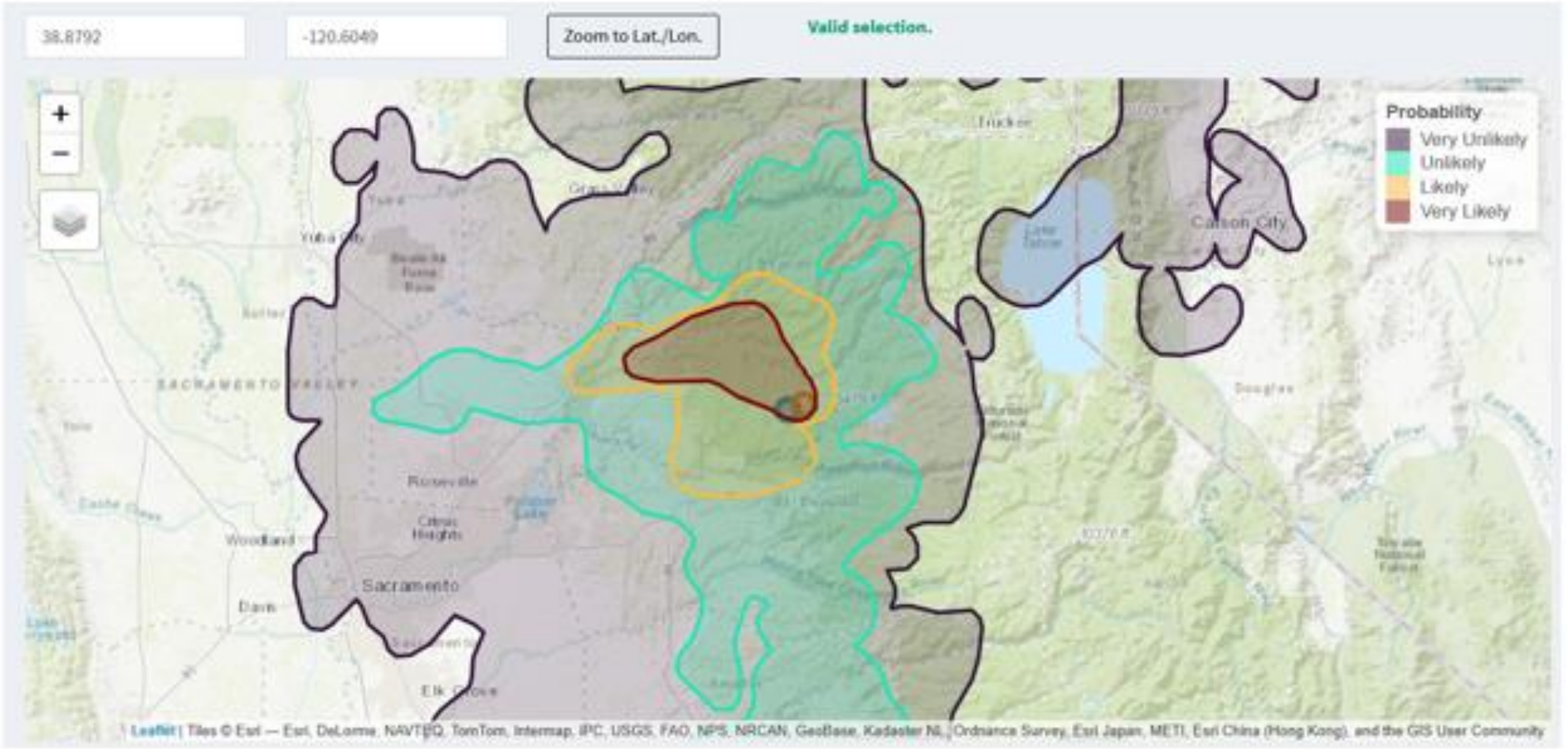
Case Study 1- SmokePath Model Inputs

SmokePath Explorer Selection Parameters	User Selection
Year[1]	2015
Filter by (Months or Weeks)	Weeks
Month(s)	n/a
Weeks(s)	46, 47, 48
Init. Height(s) (% of Boundary Layer Height)[2]	10, 50
Init. Hour(s) (Local Time)	00, 06, 12, 18
Color Scheme	Select desired color scheme
Transport and Weather Outputs	Select
Potential Receptors	Select

SmokePath Output for the Mountain Prescribed Fire (2015)

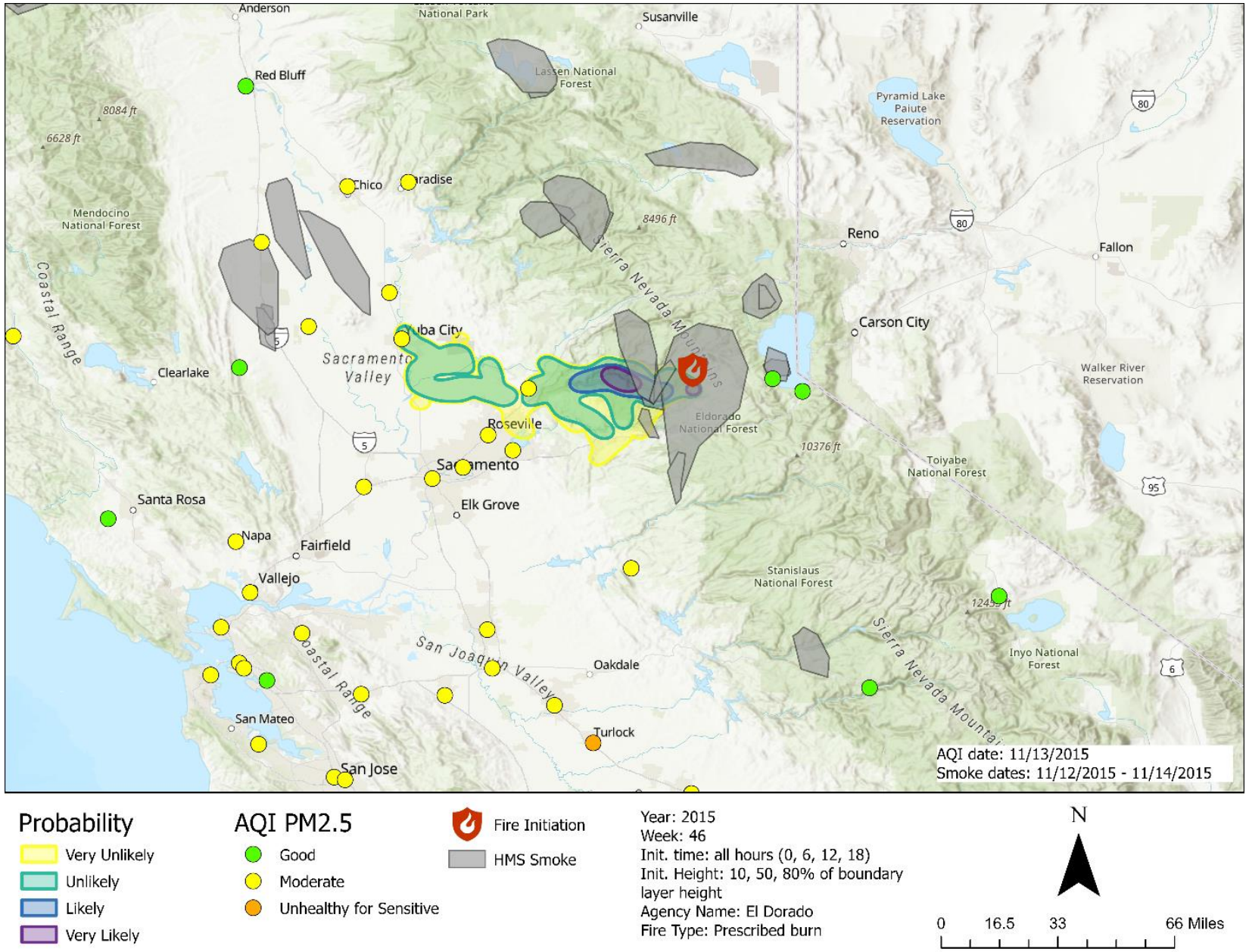


SmokePath Output for the Mountain Prescribed Fire (2001-2020)

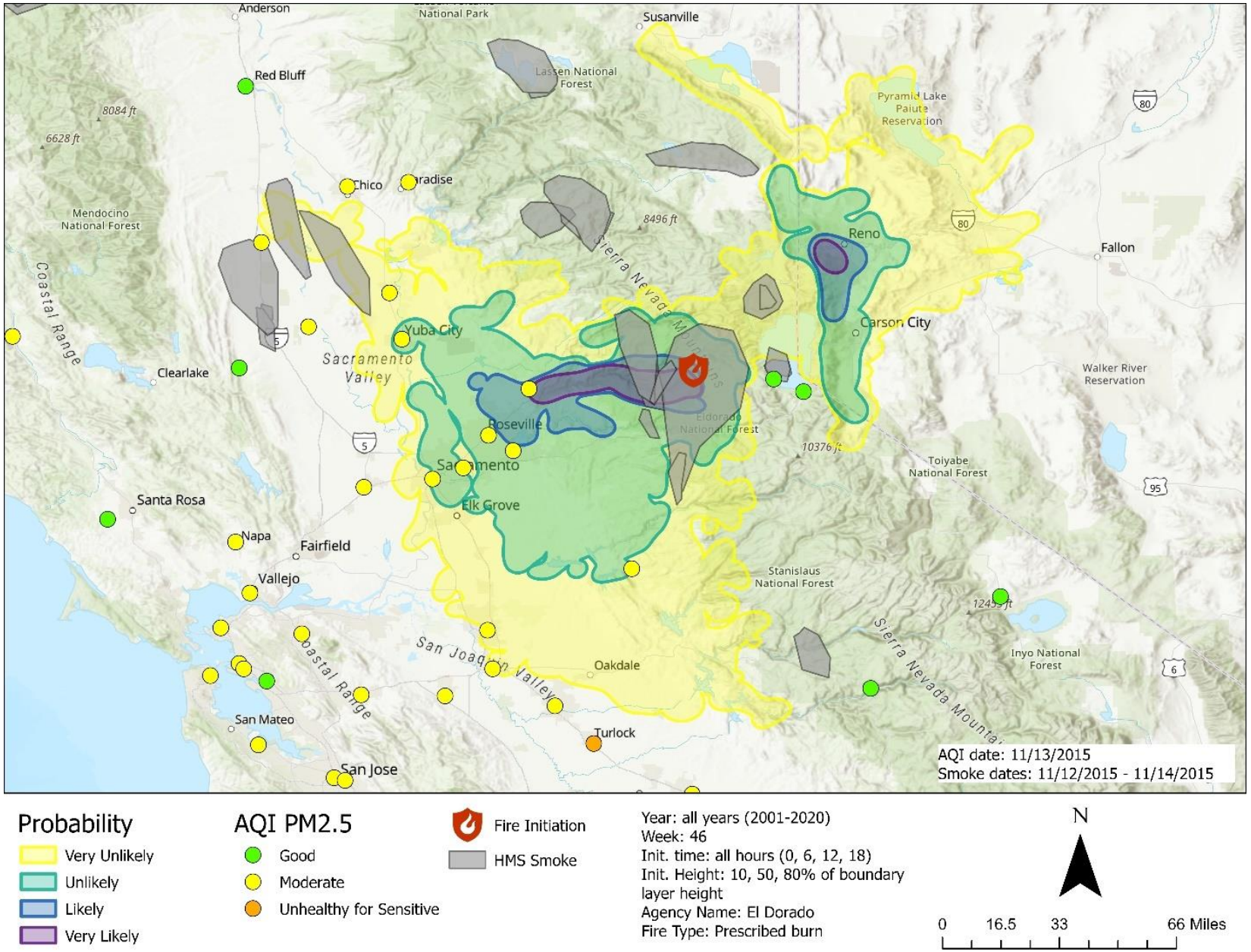


By incorporating more trajectory data into the modeled transport scenario, the variation in transport outcomes increases, leading to a larger spatial coverage in probability contours.

SmokePath Validation for the Mountain Prescribed Fire (2015)



SmokePath Validation for the Mountain Prescribed Fire (2001-2020)



Expanded Data: Meteorology and Potential Receptors

Meteorology 2015

Meteorology* ?

*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	2.56	3.89	3.03
Max Wind Speed (m/s)	5.91	8.85	7.23
Wind Direction (°)	88	122	108
Relative Humidity (%)	48.2	56.6	52.7
Vapor Pressure Deficit (kPa)	0.26	0.56	0.45
Temperature (°F)	31.3	42.1	37.5
Temperature (°C)	-0.4	5.6	3.0
Soil Moisture (kg/m^2)	206	213	210
AM Transport Wind Speed (m/s)	4.96	5.96	5.61
PM Transport Wind Speed (m/s)	6.29	8.78	7.20
AM Mixing Height (m)	1,392	1,983	1,771
PM Mixing Height (m)	2,090	3,171	2,718
AM Ventilation Index (m^2/s)	6,902	11,709	10,056
PM Ventilation Index (m^2/s)	13,138	25,411	19,754

Meteorology 2001-2020

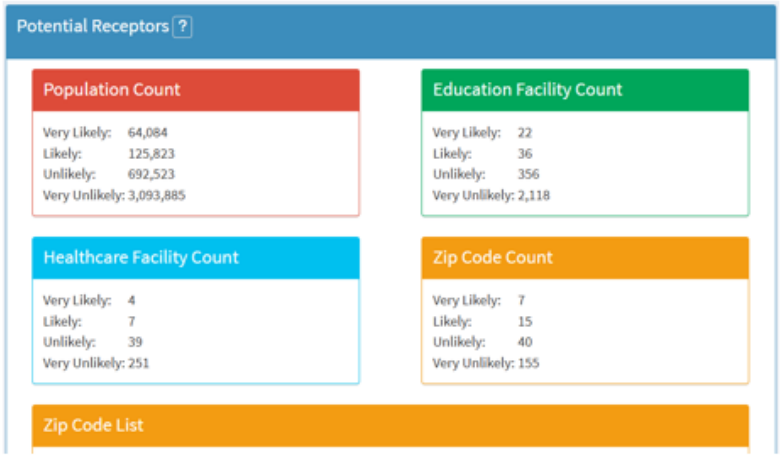
Meteorology* ?

*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	0.87	9.28	3.32
Max Wind Speed (m/s)	4.56	14.37	7.69
Wind Direction (°)	48	215	131
Relative Humidity (%)	25.3	79.9	49.3
Vapor Pressure Deficit (kPa)	0.00	1.05	0.54
Temperature (°F)	21.8	55.0	40.9
Temperature (°C)	-5.6	12.8	5.0
Soil Moisture (kg/m^2)	146	225	182
AM Transport Wind Speed (m/s)	1.40	22.58	7.49
PM Transport Wind Speed (m/s)	3.50	25.24	9.30
AM Mixing Height (m)	640	3,026	1,535
PM Mixing Height (m)	1,049	3,622	2,627
AM Ventilation Index (m^2/s)	1,238	47,831	12,204
PM Ventilation Index (m^2/s)	4,270	72,217	25,009

Potential Receptors

Potential Receptors 2015



Indicates the number of people, facilities, and zip codes potentially impacted

Case 1: The Mountain Fire

- This case highlights that is often best to use the full climatology (all years) to represent future prescribed fire impacts for a burn, as more variability and possible outcomes are represented, especially for large multi-day fires.
- Though the resolution of CANSAC model runs is high, there are some uncertainties when comparing individual days to a multi-week consensus.
- This highlights why the tool should be used for planning and does not to replace a day-of go/no-go.

Case Study 2 – The San Diego Prescribed Fire

Objective: Determine likely smoke impacts from the San Diego Prescribed Fire in central San Diego County, California.

Area: 5,800 acres

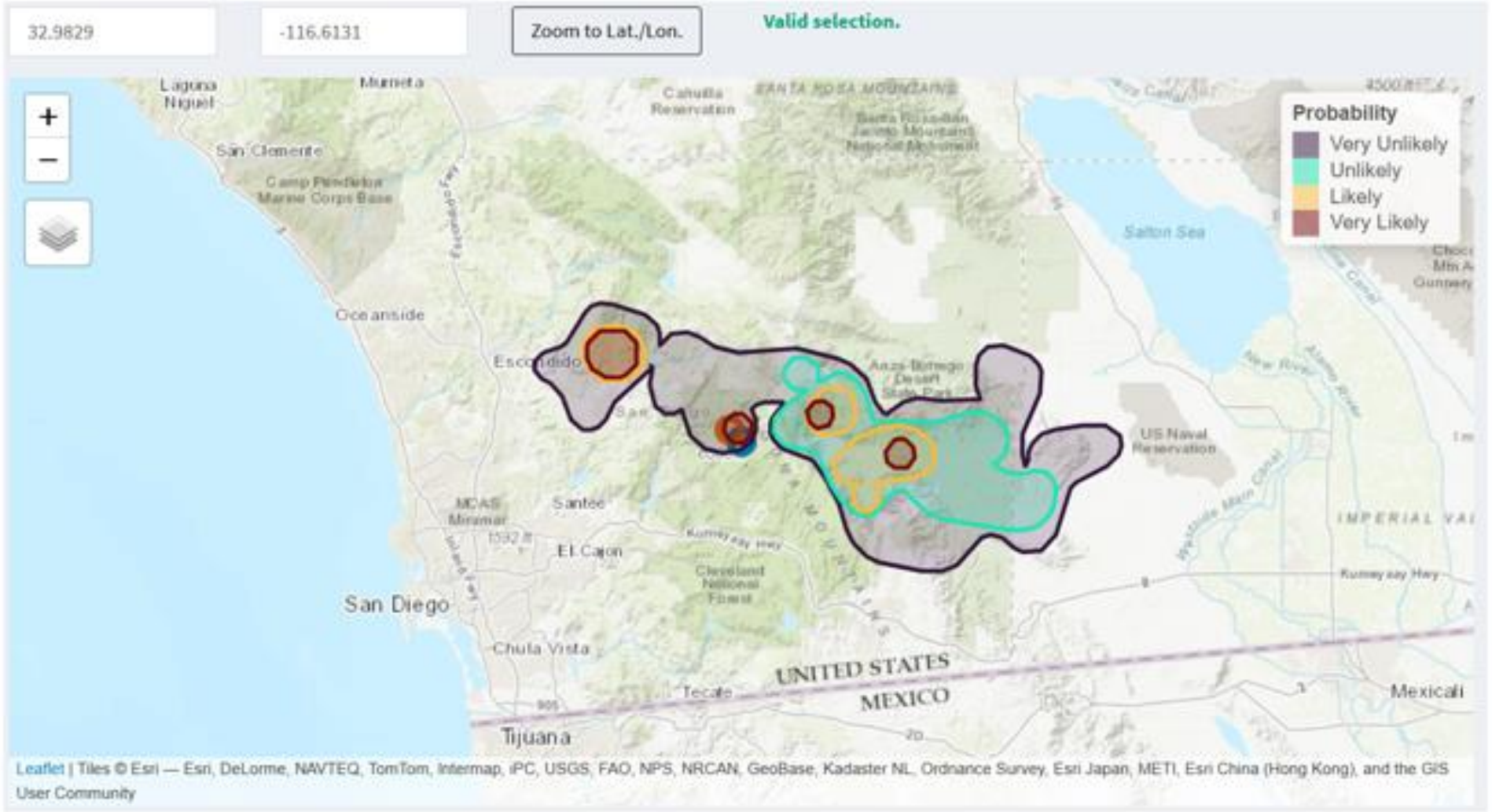
Duration: January 19-20, 2012

Lat, Lon: 32.9829, -116.613

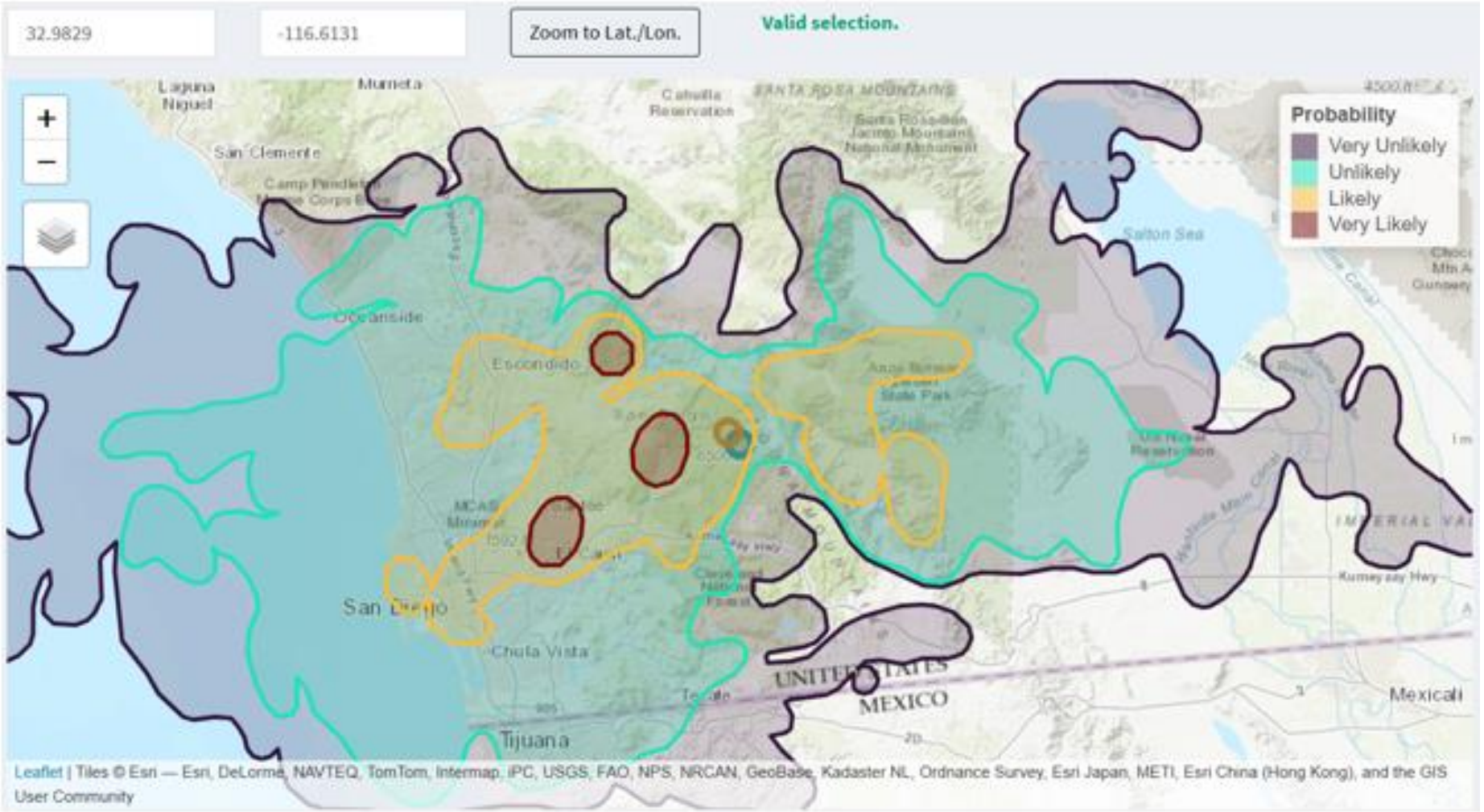
Case Study 2 - SmokePath Model Inputs

SmokePath Explorer Selection Parameters	User Selection
Year[1]	2012
Filter by (Months or Weeks)	Weeks
Month(s)	n/a
Weeks(s)	3
Init. Height(s) (% of Boundary Layer Height)[2]	10, 50
Init. Hour(s) (Local Time)	12, 18, 00
Color Scheme	Select desired color scheme
Transport and Weather Outputs	Select
Potenial Receptors	Select

SmokePath Output for the San Diego Prescribed Fire (2012)

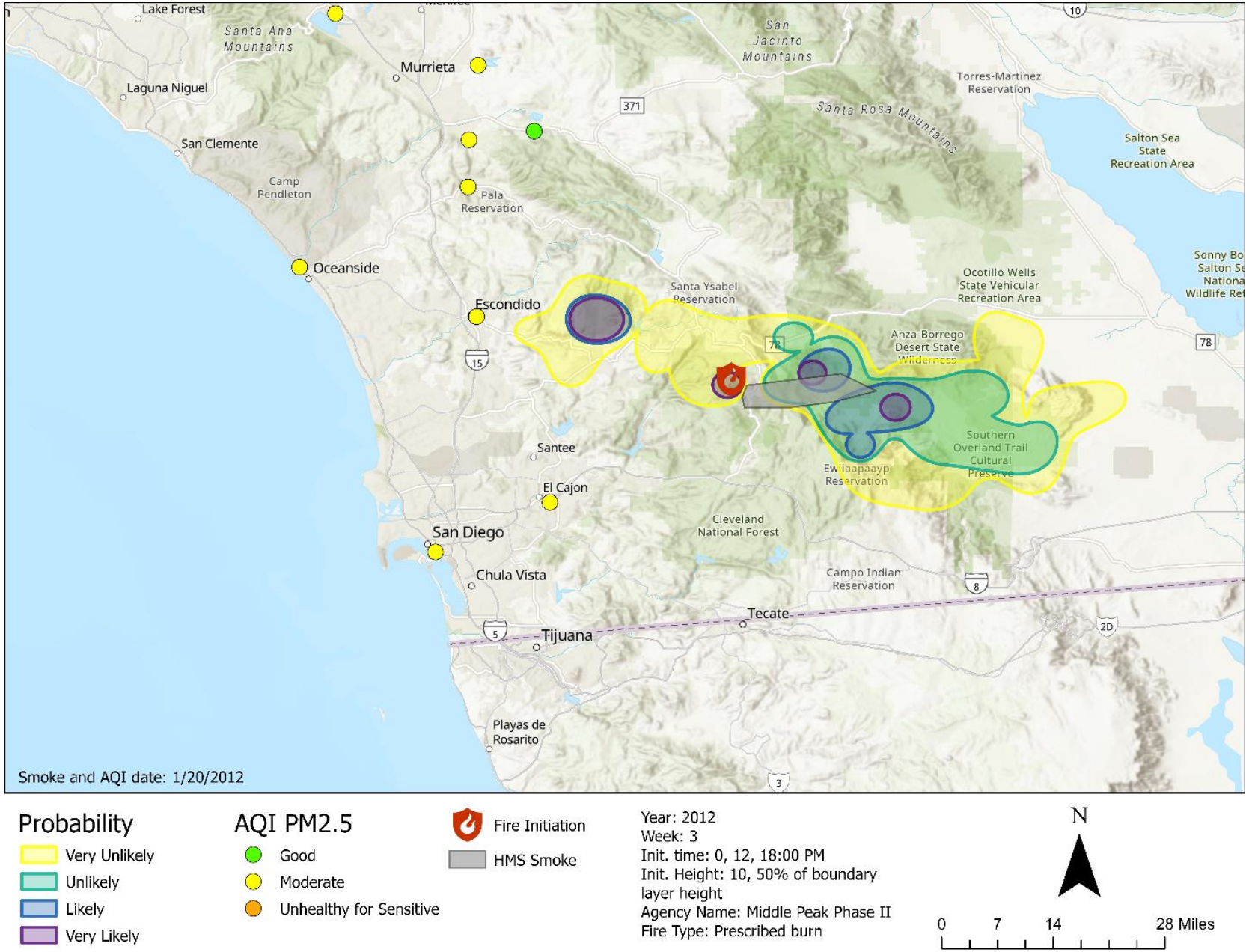


SmokePath Output for the San Diego Prescribed Fire (2001-2020)

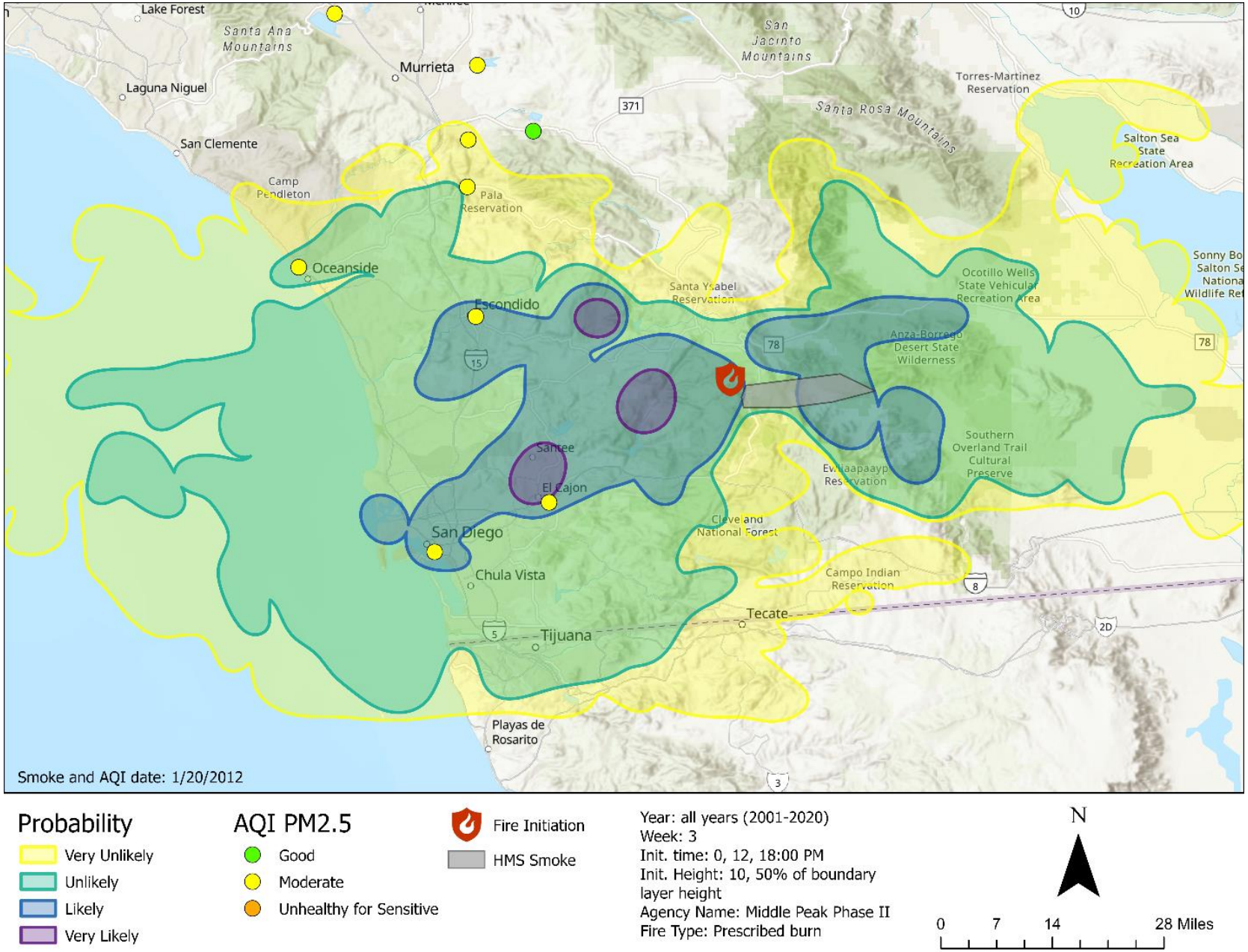


By incorporating more trajectory data in the modeled transport scenario, the variation in transport outcomes increases, leading to larger spatial coverage in probability contours.

SmokePath Validation for the San Diego Prescribed Fire (2012)



SmokePath Validation for the San Diego Prescribed Fire (2001-2020)



Case 2: The San Diego Prescribed Fire

- By incorporating more trajectory data into the modeled transport scenario, the variation in transport outcomes increases, leading to a larger spatial coverage in probability contours.
- In this case, a strong La Niña was present in 2012, making the single year representation more appropriate than the full climatology.
- Depending on time of year and current El Niño/La Niña events, it is important to tailor user selections.

Case Study 3 – Planning for Prescribed Fire in Sonoma County, CA

Objective: Identify time periods when environmental conditions and operational resources are favorable to conduct a prescribed burn. Specifically, determine whether March or April is more optimal for a prescribed burn based on climatological data.

Area: Eastern Sonoma County

When: March or April 2024

Lat, Lon: 38.4305, -122.628

Case Study 3 - SmokePath Model Inputs

SmokePath Explorer Selection Parameters	User Selection
Year	Select All
Filter by (Months or Weeks)	Month
Month(s)	March
Weeks(s)	n/a
Init. Height(s) (% of Boundary Layer Height)[1]	10, 50
Init. Hour(s) (Local Time)	12:00 PM
Color Scheme	Select desired color scheme
Transport and Weather Outputs	Select
Potenial Receptors	n/a for this case study

Case Study 3 – Model Outputs

Meteorological Output for March

Meteorology* ?

*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	0.86	7.38	2.48
Max Wind Speed (m/s)	3.65	9.17	5.79
Wind Direction (°)	39	349	174
Relative Humidity (%)	39.9	98.6	68.0
Vapor Pressure Deficit (kPa)	0.10	1.26	0.54
Temperature (°F)	37.3	65.9	49.5
Temperature (°C)	3.0	18.8	9.7
Soil Moisture (kg/m²)	216	316	265
AM Transport Wind Speed (m/s)	2.93	17.42	6.63
PM Transport Wind Speed (m/s)	3.87	14.73	7.35
AM Mixing Height (m)	1,077	2,667	1,827
PM Mixing Height (m)	1,607	5,579	3,086
AM Ventilation Index (m²/s)	3,674	35,304	12,537
PM Ventilation Index (m²/s)	9,138	44,346	22,663

Meteorological Output for April

Meteorology* ?

*for selected period based on daily averages.

Variable	Min.	Max.	Average
Wind Speed (m/s)	0.37	3.75	1.93
Max Wind Speed (m/s)	3.37	8.10	5.70
Wind Direction (°)	79	345	222
Relative Humidity (%)	32.3	89.5	64.1
Vapor Pressure Deficit (kPa)	0.16	1.87	0.70
Temperature (°F)	40.4	69.0	53.9
Temperature (°C)	4.7	20.5	12.2
Soil Moisture (kg/m²)	216	313	256
AM Transport Wind Speed (m/s)	1.60	10.68	5.48
PM Transport Wind Speed (m/s)	3.61	11.89	6.83
AM Mixing Height (m)	987	2,910	1,821
PM Mixing Height (m)	2,506	4,850	3,388
AM Ventilation Index (m²/s)	1,583	22,960	10,265
PM Ventilation Index (m²/s)	10,967	39,157	23,093

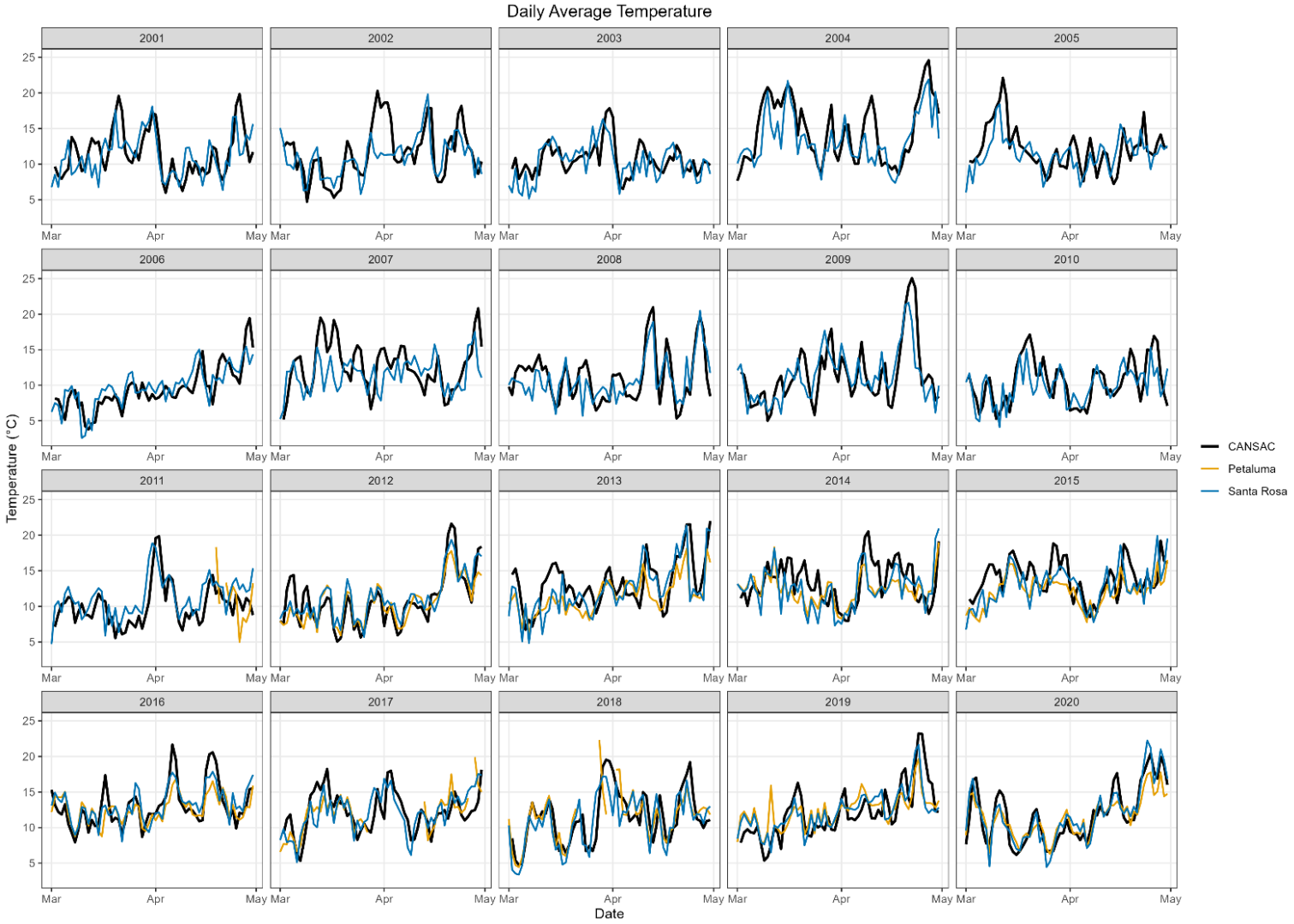
The fire weather statistics from March to April indicate seasonal changes, such as increased average temperatures, increased boundary layer heights, and lower soil moisture.

The transport wind speed (the mean of the horizontal wind speed from the surface to the mixing height boundary) is faster on average in March than in April.

Case Study 3 – Model Validation

SmokePath modeled data can be compared to CANSAC and observed data from the Automated Surface Observing System (ASOS)

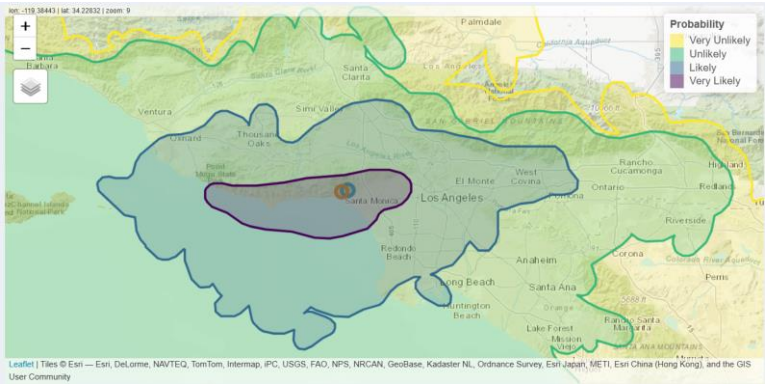
The image on the right shows daily average temperature data from CANSAC and the Petaluma and Santa Rosa ASOS stations in Sonoma County



Case 3: Planning for Prescribed Fire in Sonoma County

- Even before considering smoke, we can narrow down to which time of year is most optimal for burn-days.
- Long-range planning can help distribute limited resources.
- The 20-yr climatology provides representation of expected weather conditions by location.

New Case: Wildfire



Data Filtering and Display

Use Presets

Custom

Year(s)

2001, 2002, 2003, 2004, 2005, 2006, 2007,

Filter by:

(•) Month(s) ( ) Week(s)

Month(s)

Jan

Week(s)

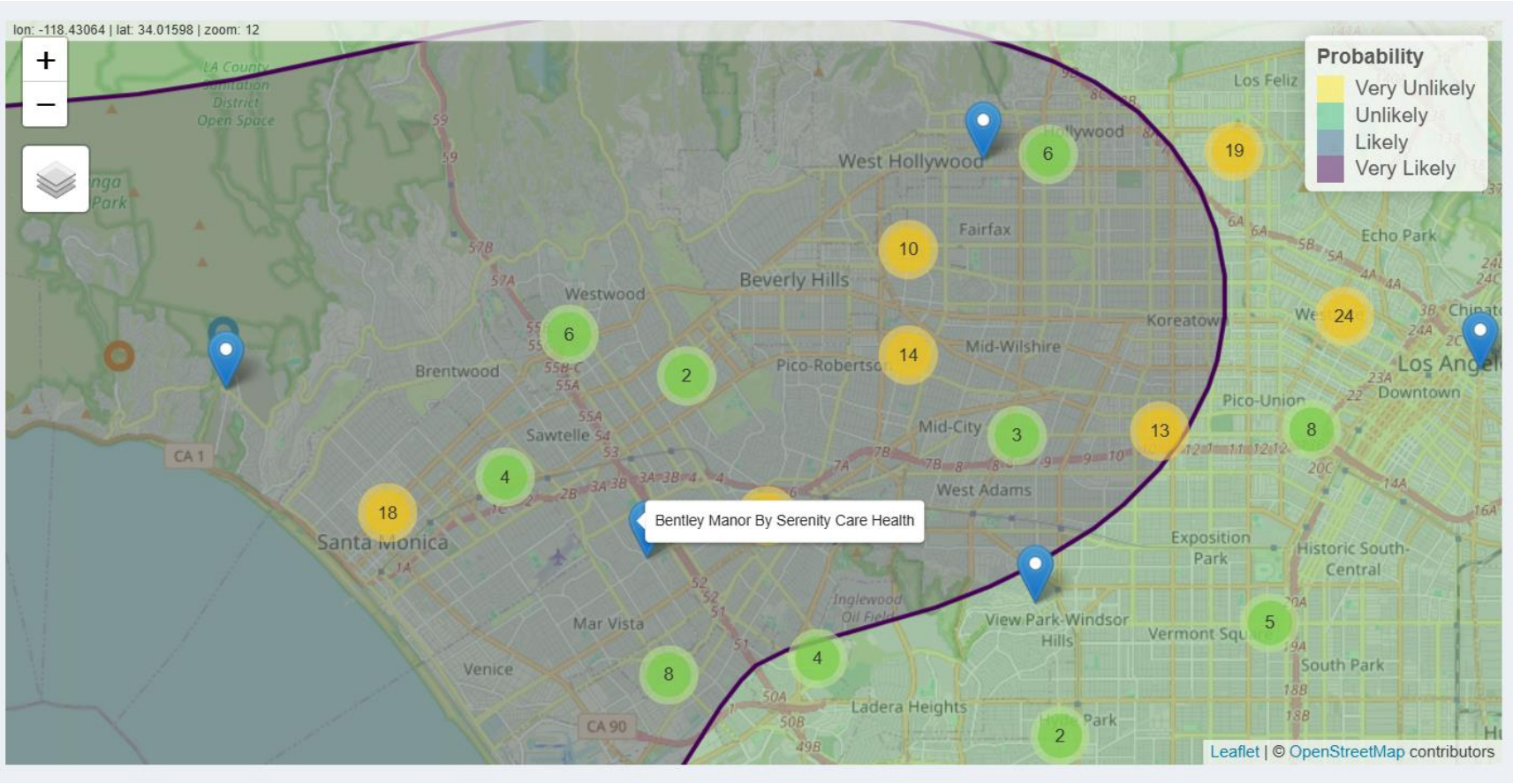
41, 42

Init. Height(s) (% of Boundary Layer Height)

10, 50, 80, 200

Init. Hour(s) (Local Time)

00:00, 06:00, 12:00, 18:00



Q&A

- Questions from the Chat
- Technical questions on:
  - Data used in the tool
  - Methods implemented
  - Using the dashboard and its parameters

Discussion

- Suggestions on additions or adjustments to make this tool more useful.
- Additional use-cases that should be highlighted in training material and guidance.
- Preferences on accessibility of the tool (hosting, integration with existing tools).

Workshop Feedback Survey

Thank you for attending!

Please take a moment to fill out the online feedback survey.

https://www.surveymonkey.com/r/298Z52X

SmokePath Explorer

A New Smoke Management Tool for California

SmokePath Explorer will be live at this location for the next several months. We will provide an update once the site moved to a permeant web location.

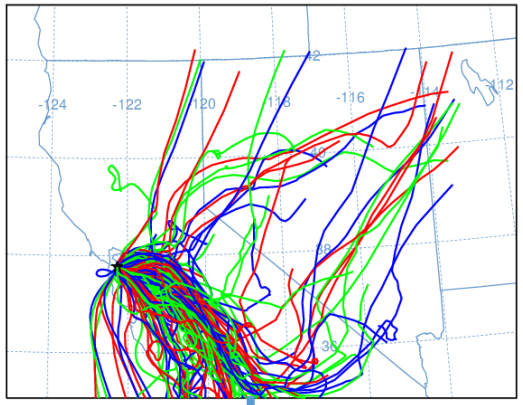
http://rstudio-connect.sonomatechdata.com/SmokePath_Explorer/

https://www.surveymonkey.com/r/298Z52X

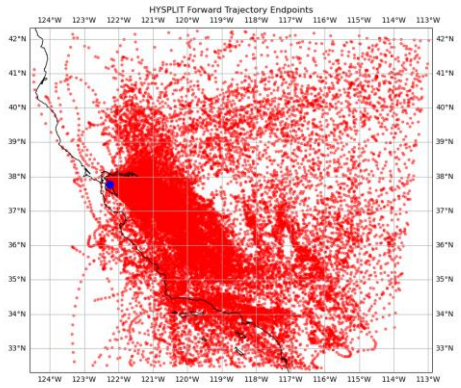
Extra Slides

Transport probability Analysis

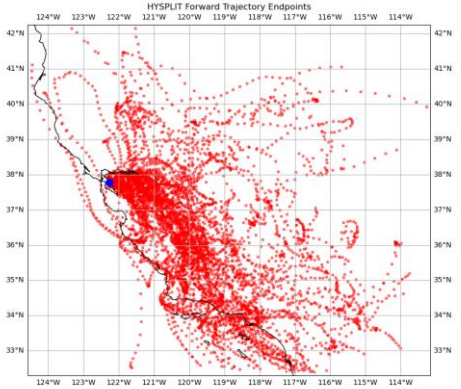
Output: Gridded air transport probability map to represent the likelihood of fire emissions reaching a location, given initial location, time and conditions of a fire.



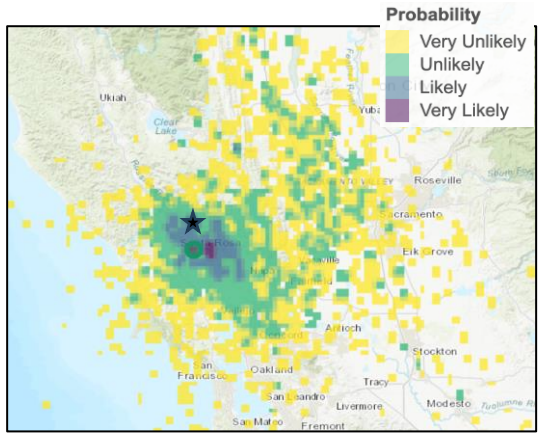
Hourly end-point extraction from trajectories



Aggregate the subset of end-point positions by user-selected time periods (week/month)

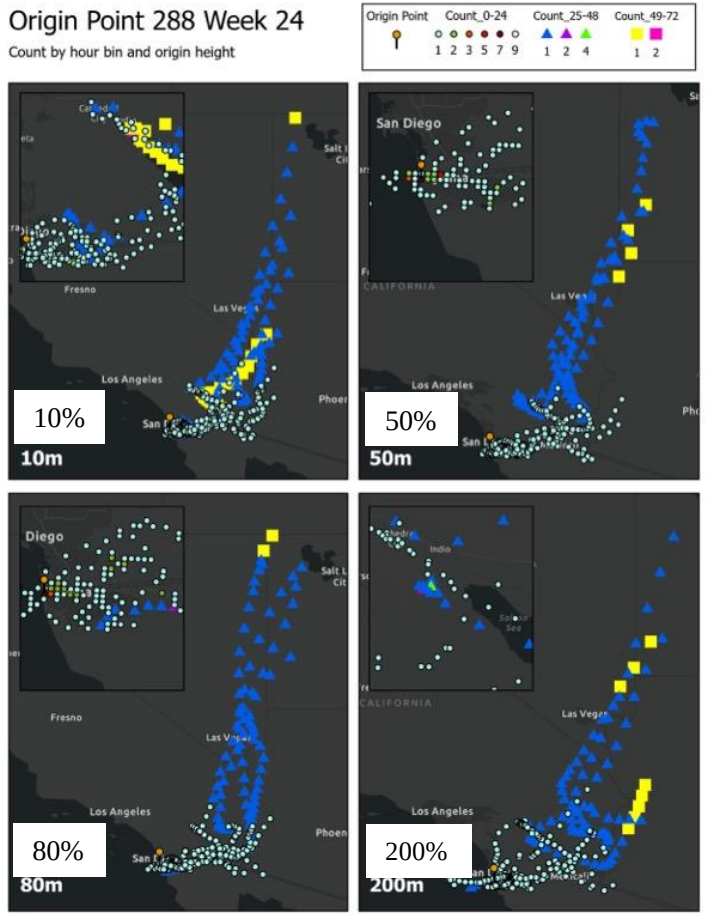


Count of trajectory points per pixel, start time, and height



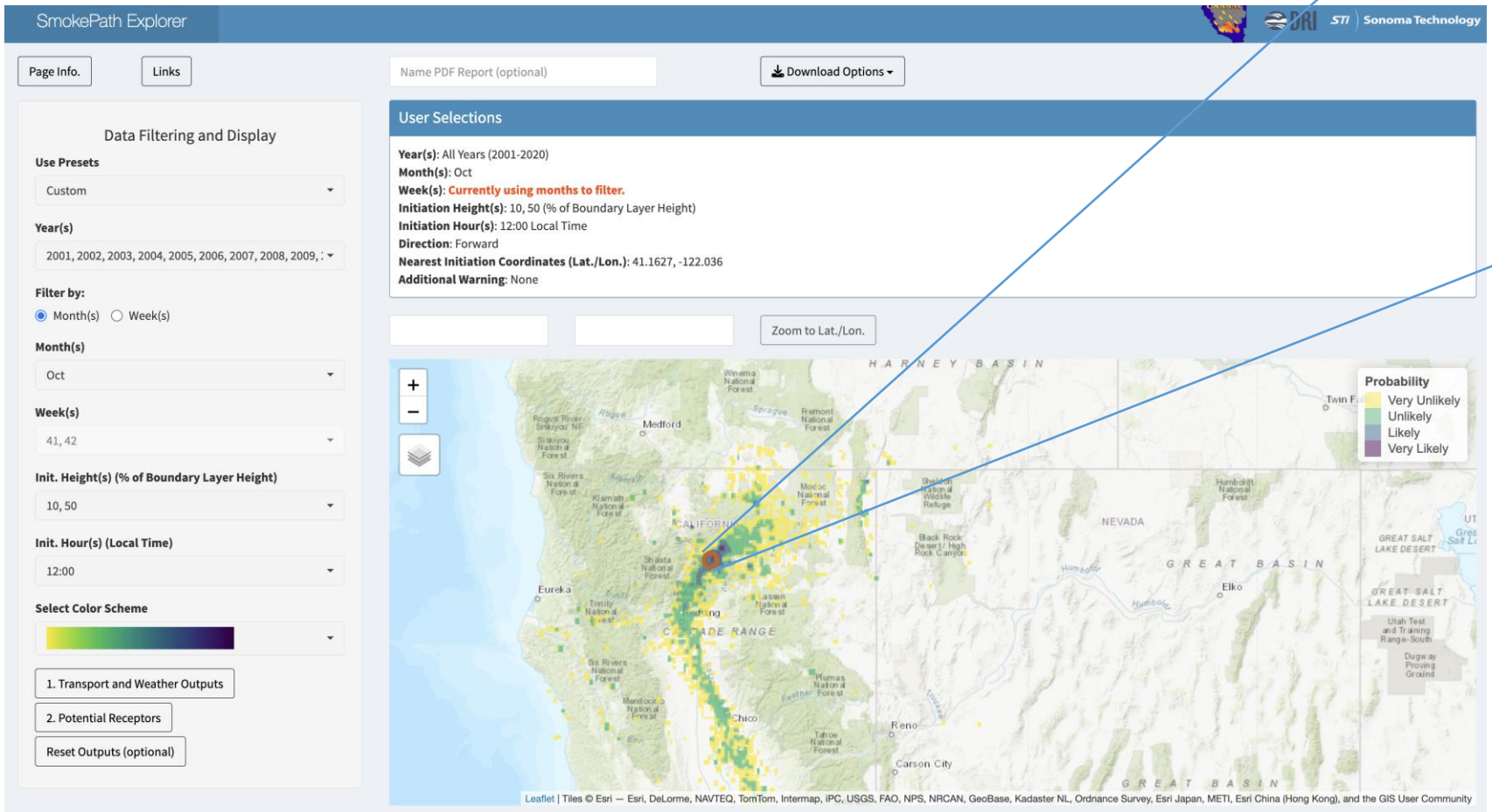
Logarithmic normalization to generate a relative transport probability

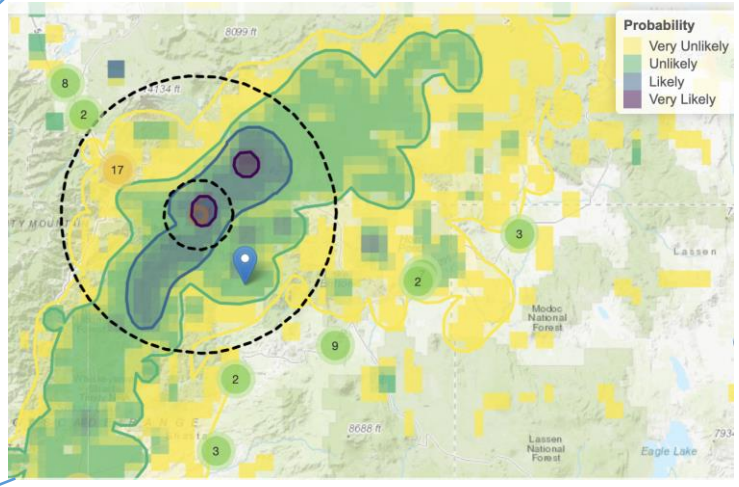
Probability levels:
10-20%: very unlikely
>20-35%: unlikely
>35-50%: Likely
>50% : very likely



Initial time: 12 pm – local time

SmokePath Visualization - User-friendly Web Application





Methods – Probability of Impacts

For a given origin point and data selection…

1. Transport probability is calculated for each downwind grid cell on a 2-km grid by dividing the log of the count of trajectory points by the log of the maximum possible count, followed by normalizing by the maximum probability (i.e., 100%).
2. Gridded transport probability is converted to contours representing multiple probability levels: 10-20% (very unlikely), 20-35% (unlikely), 35-50% (likely), >50% (very likely).
3. Receptor data are spatially joined with transport probability contours to identify and summarize receptors at risk of smoke exposure.