Air Quality Impacts of the January 2025 Los Angeles Wildfires: Insights from public data sources

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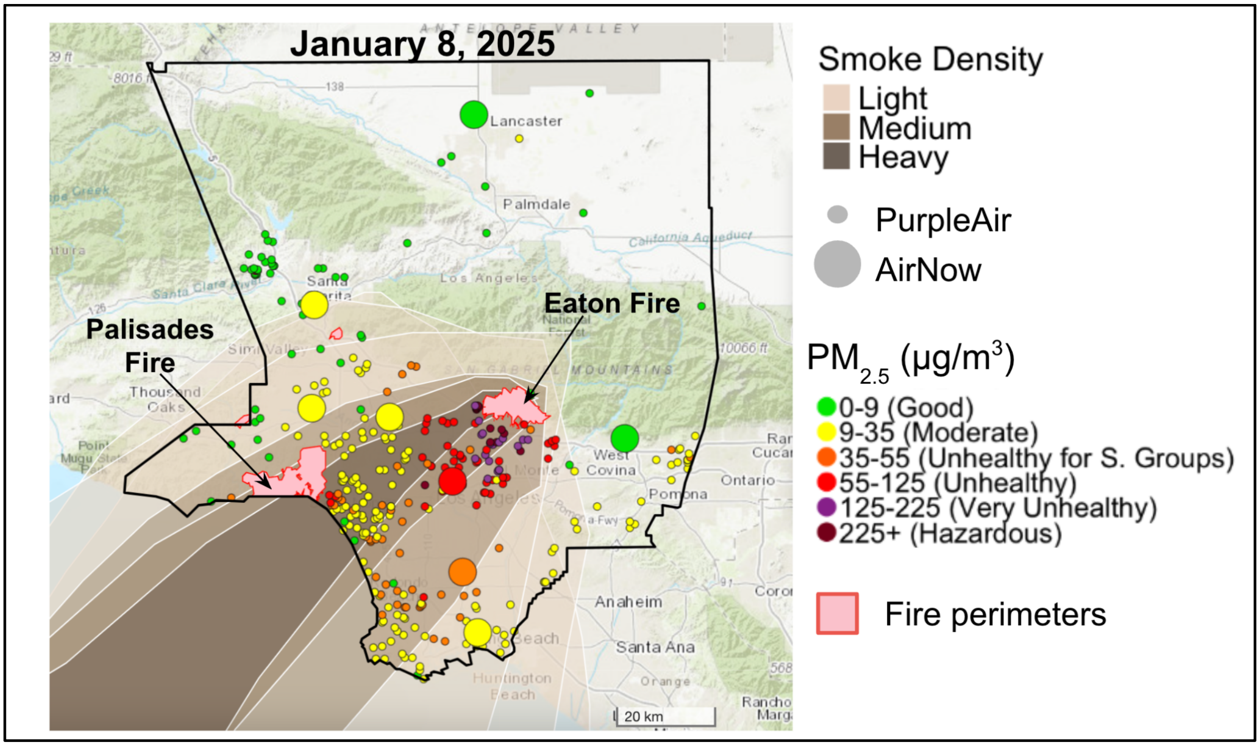
Abstract
Smoke from the Los Angeles wildfires that started on January 7, 2025 caused severe air quality impacts across the region. Government agencies released guidance on assessing personal risk, pointing to publicly available data platforms that present information from regulatory and low-cost monitoring networks. Additional satellite-based products provide useful supplementary information during dynamic wildfire smoke events. We evaluate the regional air quality impacts of the fires through publicly available fine particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) observations. Specifically, we analyze pollutant data from regulatory monitoring stations, PurpleAir sensors, the TEMPO and TROPOMI satellite sensors, and HMS Smoke Plumes during the January 2025 Los Angeles wildfires. The most extreme air quality impacts were observed on January 8 and 9, particularly in the southern half of Los Angeles County. While smoke impacts were largely consistent across all evaluated data sources, differences in the spatial and temporal resolution of each product may affect interpretability for end users. This study underscores the importance of integrating multiple air quality data sources and improving accessibility to enhance public health messaging during wildfire events.

Keywords
Wildfire smoke, public health, air quality, satellite data, low-cost sensors, regulatory monitors

Synopsis
This study highlights the need to integrate diverse publicly available air quality data sources to improve public health messaging during wildfire events.

Graphical abstract:



Introduction

On January 7th, 2025, several wildfires ignited in Los Angeles (LA), California. Antecedent hot and dry conditions coupled with abundant vegetation resulted in widespread dry fuels [1–3]. Extreme winds rapidly spread embers once the wildfires ignited. The two largest fires, Palisades and Eaton, burned a combined 37,728 acres, damaged or destroyed 18,295 structures, and resulted in at least 29 civilian fatalities [4,5]. Several other smaller fires, including the Hughes, Hurst, and Kenneth fires also impacted different LA communities throughout the month [6–8].

Wildfires produce smoke which can affect communities far from the flames themselves. Smoke is a complex mixture of fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide, volatile organic compounds, nitrogen oxides, ozone, metals, and other pollutants [9-11]. Wildfire smoke exposure has been linked to respiratory-related mortality and morbidities, cardiovascular diseases, adverse pregnancy outcomes, and mental health impacts [12,13].

Government agencies provide guidance for individuals to assess their risk and reduce smoke exposure through strategies like indoor air filtration, masking, and going to clean air shelters [14–16]. The first recommendation is typically to check the Air Quality Index (AQI), an U.S. Environmental Protection Agency (EPA) air pollution risk communication tool. The AQI contains six categories, ranging from 'Good' to 'Hazardous.' While the AQI covers all pollutants listed under the National Ambient Air Quality Standards (NAAQS), $PM_{2.5}$ is often the main focus of smoke-related guidance as it is a primary component of wildfire smoke.

Downwind air quality changes quickly during wildfires. There are several publicly available datasets providing rapid information, which vary in accessibility and pollutants that are included. The AirNow Fire and Smoke Map is commonly recommended by federal and state agencies [15,17]. This map reports real-time pollutant concentrations from government monitors and low-cost sensors, fire locations, and smoke plumes from satellites. Low-cost sensor networks like PurpleAir can also be accessed directly via their website[18]. Additionally, satellite observations are available from agency websites, but often require advanced knowledge to interpret the information.

The January 2025 LA wildfires caused significant regional air quality deterioration. Providing the public with understandable and accurate pollution information is crucial to risk reduction and for informing future health impacts studies. We compare publicly available $PM_{2.5}$, NO_2, and smoke plume imagery from ground stations and satellites. Our purpose is to (1) determine whether pollutant concentrations during the wildfires differed from baseline and (2) to compare trends across publicly available data sources.

Methods

Data sources

Ground monitors and low-cost sensors

We obtained hourly $PM_{2.5}$ and NO_2 concentrations from eight and 13 regulatory monitoring stations, respectively, from the AirNow network and $PM_{2.5}$ from 728 PurpleAir monitors throughout LA County. For inclusion in our analysis, stations needed to report measurements during the 'baseline period' (12-24-2024 to 1-6-2025 and 1-15-2025 to 1-21-2025) and the 'fire-impacted period' (1-7-2025 to 1-14-2025). The regulatory station data were accessed via AirNow, which provides preliminary U.S. EPA Air Quality System (AQS) measurements from Federal Reference Methods or Federal Equivalent Methods. PurpleAir data were accessed via their API. PurpleAir stations contain two Plantower sensors and temperature and humidity sensors, which sample every second. We followed the QA/QC process outlined in Connolly et al. (2022) and applied an EPA-developed correction to improve comparability to regulatory monitors, [19,20] then averaged to hourly timesteps. Some PurpleAir monitors did not collect data during the fires because of power outages or locations in the burn scar and were not included.

Satellite data

Satellites provide complementary information to ground stations on spatiotemporal distribution of pollution throughout the vertical atmospheric column. We downloaded plume and NO_2 data from three satellite data sources for the 8 days following the first wildfire ignition.

The AirNow Fire and Smoke Map includes smoke plumes from the National Oceanic and Atmospheric Administration Hazard Mapping System (HMS). HMS consists of manually delineated smoke plumes from geostationary satellites (GOES) and sensors on polar-orbiting satellites (VIIRS, MODIS). The plumes are classified into three smoke density classes (light, medium, and heavy), based on the opacity of smoke in the images. The presence of smoke in the atmosphere, however, does not always correlate to surface-level pollution [21].

NO_2 data were obtained from the TROPOspheric Monitoring Instrument (TROPOMI) aboard the Sentinel-5 Precursor polar orbiting satellite. TROPOMI collects global daily measurements of tropospheric NO_2, which we downloaded from Google Earth Engine (GEE) [22,23]. GEE regrids TROPOMI from Level 2 to Level 3, from a spatial resolution of 5.5 x 3.5 km^2 to 0.01° x 0.01°, using the *harpconvert* tool and removing tropospheric NO_2 pixels with quality assurance values < 75%. We also obtained NO_2 from Tropospheric Emissions: Monitoring of Pollution (TEMPO), a geostationary satellite UV-visible spectrometer. TEMPO provides vertically integrated, hourly, 2.1 x 4.5 km^2 pollutant measurements. We averaged the retrievals within the Level 3 product to estimate daytime average column NO_2 measurements. TEMPO observations are publicly available, but currently have provisional status [24].

Analysis

A linear mixed-effects model was used to assess differences in $PM_{2.5}$ levels between the baseline and fire-impacted periods, adjusting for meteorological conditions, with monitoring location included as a random effect. We also determined the percentage of total hours during each period when $PM_{2.5}$ concentrations were within each AQI category. We analyzed HMS plumes to track the extent of smoke density and compared to regulatory ground measurements. We evaluated the linear relationship between average daytime ground measurements (13:00-23:00 UTC to match TEMPO) and the average column density of the grid cell co-located with each station. For TROPOMI, we used the same approach but compared the hourly ground station measurement corresponding with the satellite overpass (13:30 local time). We calculated correlations between HMS plume density, ground station $PM_{2.5}$ and satellite column NO_2 estimates.

Results and Discussion

$PM_{2.5}$

During the baseline period, the highest daily average $PM_{2.5}$ concentrations were observed from both the regulatory and PurpleAir monitors across the southern portion of the county, where industrial, residential, and traffic-related sources of pollution are concentrated (Figure 1, Figure S1). New Year's Eve $PM_{2.5}$ falls within our baseline period, during which the South Coast Air Quality Management District (SCAQMD) issued an air quality advisory due to fireworks [25]. Additionally, SCAQMD issued a series of 'No Burn' advisories during the last week of December, due to stagnant atmospheric conditions [26]. As a result of these conditions, AQI levels of Moderate to Unhealthy were observed during the baseline period for six of the eight regulatory monitors (Figure 1).

As the Palisades and Eaton fires intensified, $PM_{2.5}$ concentrations in southern LA County increased, with daily average $PM_{2.5}$ concentrations at the downtown LA regulatory monitors reaching 101.7 μg/m³ on January 8th and Compton reaching 52.3 μg/m³ on January 9th (Figure 1, Figure S1). Although county-wide average daily concentrations during the fire-impacted week (16.3 μg/m³) were not significantly higher than those during the baseline period (16.2 μg/m³), hourly measurements show a greater proportion of hours in higher AQI categories: 'Unhealthy' (6.2% vs. 1.7%), 'Very Unhealthy' (0.33% vs. 0.10%), and 'Hazardous' (0.20% vs. 0.05%) during the fire-impacted week compared to baseline (Supplementary Text S1, Figure S2). At individual sites, such as in downtown LA, the increase of hours spent at upper AQI levels was even more notable: ‘Unhealthy for Sensitive Groups’ rose from 9.5% to 13.0%, ‘Unhealthy’ from 0.8% to 18.8%, ‘Very Unhealthy’ from 0.0% to 2.1%, and ‘Hazardous’ from 0.0% to 1.6% (Figure S2). The PurpleAir network provides neighborhood-level variations in $PM_{2.5}$ closer to the burn areas. For example on January 8th, two sensors within 2 km of the Eaton Fire reached an average daily concentrations >300 μg/m³, while 10 additional sensors, ranging from ~0.5-7.5 km from fire, exceeded 225 μg/m³ (Hazardous AQI) (Figure S2)[27].

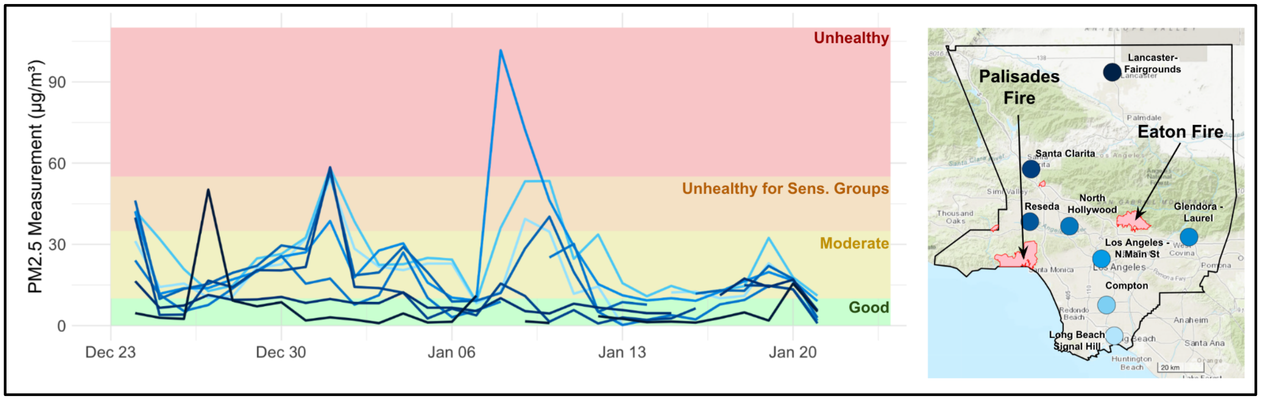


Figure 1. Daily average $PM_{2.5}$ concentrations from AirNow monitoring locations. Shading represents the concentration cutoffs for 'Good' (green), 'Moderate' (yellow), 'Unhealthy for Sensitive Groups' (orange), and 'Unhealthy' (red) AQI levels. Negative $PM_{2.5}$ measurements were omitted. The map on the right shows monitor locations with fire perimeters indicated in red from the National Interagency Fire Center [28]. Basemap: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community.

Smoke Plumes

The HMS plumes shown in Figure 2 highlight the dynamic nature of smoke transport. The first satellite detections of smoke from the Palisades Fire show the plume extending over the Pacific Ocean but leaving regulatory monitoring stations unimpacted. By January 8th and 9th, after the ignition of the Eaton Fire, light to heavy density smoke covered the southern half of the county, corresponding with elevated daily average $PM_{2.5}$ concentrations at several regulatory monitors and offshore transport of the plumes. By January 10th, light to medium density smoke covered most of LA County, with the southern half of the county most heavily impacted. When wind conditions picked up again on January 11th, smoke was pushed back offshore, reducing plumes over populated areas.

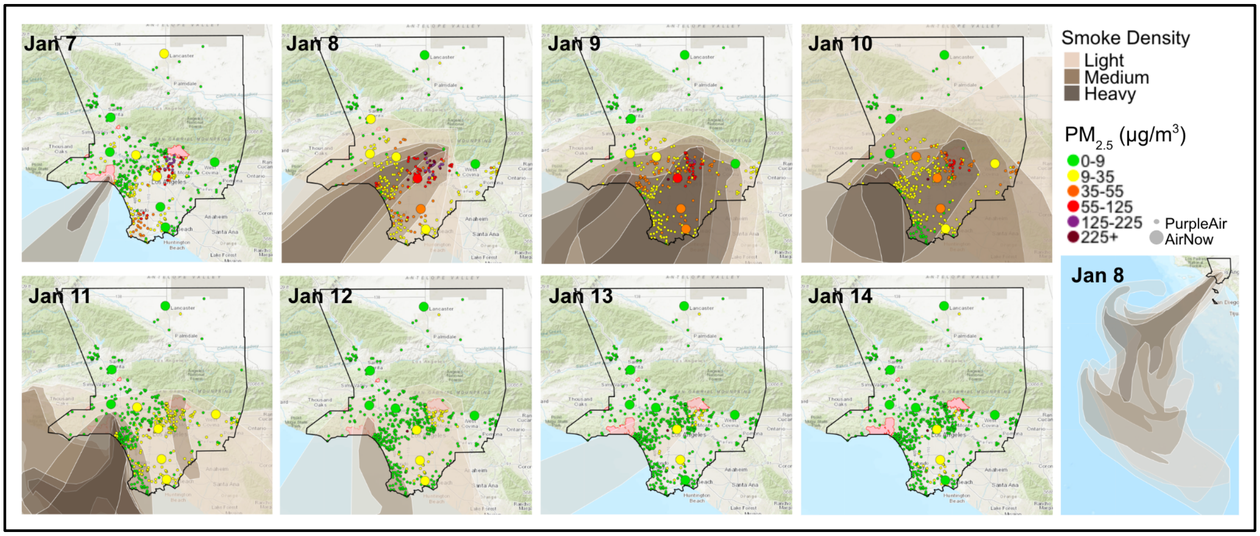


Figure 2. Daily HMS smoke plumes with average daily $PM_{2.5}$ concentrations from AirNow (large circles) and PurpleAir (small circles). Concentration bins correspond to the $PM_{2.5}$ AQI cutpoints (i.e. Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy, Hazardous). The map on the far right displays the full spatial extent of the smoke plume on January 8th. Note that the Eaton Fire began after sunset the evening of January 7, so satellites did not detect the fire until the following day. Thus, while the first map depicting January 7 shows elevated $PM_{2.5}$ concentrations from PurpleAir monitors close to the Eaton Fire, there is a lag in the ability to visualize those impacts via the HMS plumes. Basemap: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community.

<u>NO_2</u>

Ground stations and other satellites measured additional smoke-contributed pollutants, including NO_2. Figure 3 shows vertical column NO_2 from TROPOMI and TEMPO for four days after ignition. Vertical column measurements represent the total amount of NO_2 integrated from the surface to the top of the troposphere, while concentrations from ground monitors reflect the near-surface mixing ratio. Each sensor observed comparable NO_2 column enhancements, including peak column number density values on January 9th (TROPOMI = 0.0012 mol/m^2, TEMPO = 0.0014 mol/m^2) and January 11th (TROPOMI = 0.0012 mol/m^2, TEMPO = 0.0012 mol/m^2). TEMPO estimates were generally higher than those captured by TROPOMI, but also contained more missing values. These missing values could be due to cloud cover or the smoke plume itself. While county-level daily average NO_2 concentrations measured at ground stations were not higher during the fire-impacted week (17.9 vs. 21.5 ppb at baseline period), five southern stations exceeded 31 ppb daily averages on January 9th, with Long Beach reaching 51 ppb (31% higher than average baseline at that station).

We found reasonable agreement between station concentrations and satellite column enhancements (TROPOMI $R^2 = 0.33$, TEMPO $R^2 = 0.55$) during the smoke-impacted period (Figure S3). Disagreements can occur when the smoke is aloft. For example, average daily NO_2

concentrations peaked on January 9th in Long Beach (51.4 ppb), which is 1.3x higher than the baseline daily average at that location and 2.4x higher than the county baseline average, but the maximum column NO_2 measurements from both sensors were located closer to the active fires. Hourly NO_2 concentrations on January 9th exceed the 53 ppb hourly NAAQS standard for 12 hours.

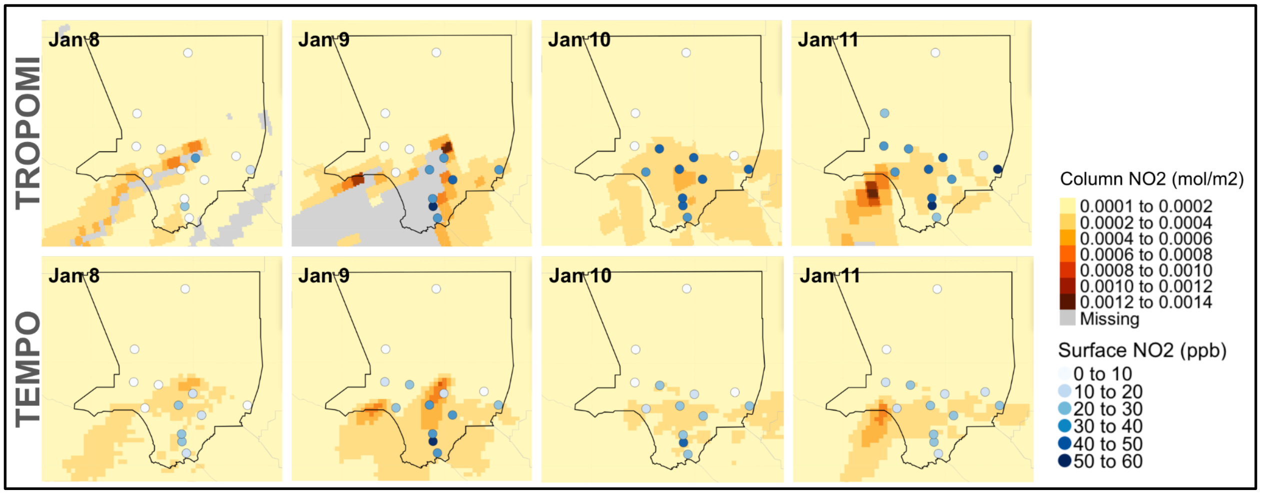


Figure 3. Daily tropospheric NO_2 vertical column number density from TROPOMI (top row) and average TEMPO NO_2 (bottom row) from a subset of days during the fire-impacted period (January 8th-11th). Surface NO_2 concentrations from regulatory ground monitors on the top row reflect the hourly measurement that coincides with the TROPOMI local flyover time (13:30). On the bottom row, we show daytime average NO_2 concentrations (13:00-23:00 UTC to match the TEMPO temporal availability).

Intercomparison of air pollution estimates and HMS smoke plumes

Figure 4 shows the distribution of ground station $PM_{2.5}$ concentrations relative to overlapping HMS smoke plumes. Higher $PM_{2.5}$ concentrations generally correspond with higher-density plumes, though this relationship is not always consistent (Figure S4). Heavier HMS smoke plumes also tended to align with higher column NO_2 measurements from TROPOMI and TEMPO. These results indicate that HMS smoke plumes may be a useful proxy for pollution during smoke events, but do not always correlate to surface exposures.

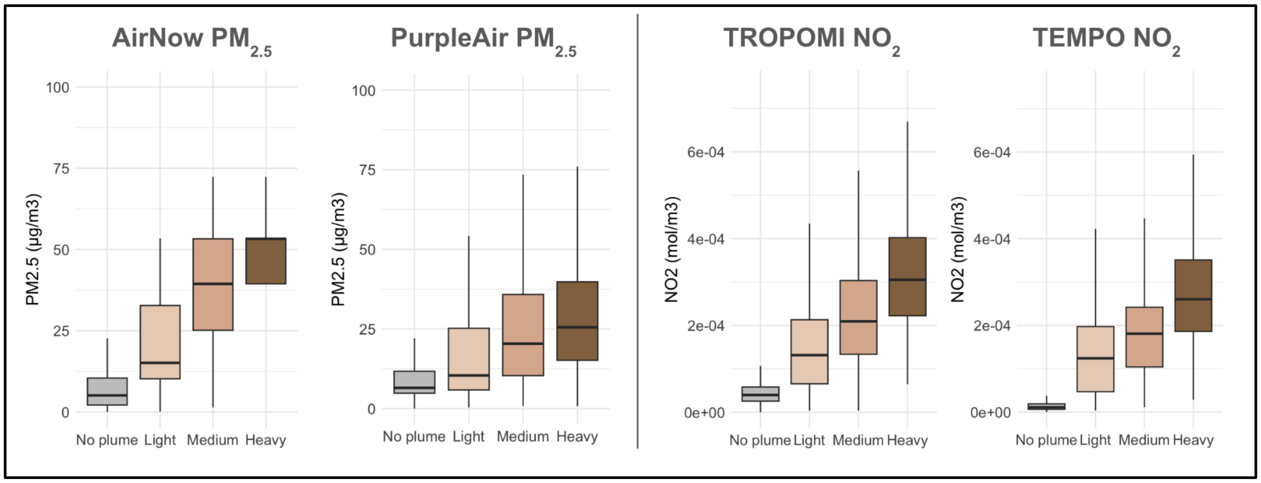


Figure 4. Box plots of daily $PM_{2.5}$ from AirNow and PurpleAir and NO_2 from TROPOMI and TEMPO in relation to HMS smoke plume density. Plume density categories are significantly positively correlated with each pollutant measurement (Spearman's rank correlations: AirNow $PM_{2.5}$: $\rho = 0.53$, $p < 0.001$, PurpleAir $PM_{2.5}$: $\rho = 0.41$, $p < 0.001$, TROPOMI NO_2: $\rho = 0.27$, $p < 0.001$, TEMPO NO_2: $\rho = 0.05$, $p < 0.001$).

Strengths, limitations, and implications for risk communication

Each data source provides unique insights into air quality during wildfires. Regulatory monitors provide highly accurate and temporally resolved information but the network is fairly sparse and the real-time data is considered preliminary. Low-cost sensors, while less accurate, provide more spatial coverage, though there are known disparities in sensor distribution across disadvantaged communities [29,30]. Satellites can also improve spatial coverage relative to ground monitoring networks but cannot immediately be translated to surface concentrations.

There are additional considerations for public risk communication. Platforms like the AirNow Fire and Smoke Map and PurpleAir allow the public to access the AQI at monitoring stations closest to where they live, work, and go to school. Different averaging times across these platforms can lead to different AQI classifications throughout the day, which may be confusing to end users. HMS smoke plumes are included on the Fire and Smoke map, making them relatively accessible for the general public. However, their lack of consistent correlation with surface-level pollutant concentration can be misleading. Satellite observations from TROPOMI and TEMPO are not readily available on existing risk communication platforms but can provide information on other pollutants besides $PM_{2.5}$.

Future work should expand on comparisons of each of these data sources with quality-controlled observations from regulatory monitors and measurements collected closer to the burned areas. We focus primarily on $PM_{2.5}$ and NO_2, though broadening to the chemical composition of particulates and other pollutants within the smoke plumes is needed to fully understand the exposure and health risks[31]. The AQI does not include information on air toxics and thus may not provide end users with a full understanding of risk. For example, measurements collected by the SCAQMD, downtown and in Compton, identified elevated lead and arsenic levels between January 7-11[32]. Relatedly, the urban setting of these fires raises questions about the smoke composition of vegetation-only versus anthropogenic fuels. While we focused on daily averages, as they are more relevant to the AQI, future analysis should further examine sub-daily extremes. Finally, agencies and researchers need to continuously assess and improve public access to these data sources. Checking local air quality conditions is the first step cited in almost every wildfire smoke-related public health communication, making it crucial that the public has access to this information.

Acknowledgements

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Supplementary materials

Supplementary Text S1:

Linear mixed effect model comparing daily AirNow $PM_{2.5}$ concentrations during the fire-impacted and baseline period, adjusting for meteorological conditions, with monitoring location included as a random effect, indicated that $PM_{2.5}$ concentrations during the fire-impacted week were not statistically higher than during the baseline period ($\beta = -0.02$, $SE = 0.24$, $t(48) = -0.08$, $p = 0.93$). This holds true when including and excluding measurements from New Years, when the SCAQMD advisory was in effect, as well as if we extend the baseline period back to November 1st, 2024.

Supplementary Figures:

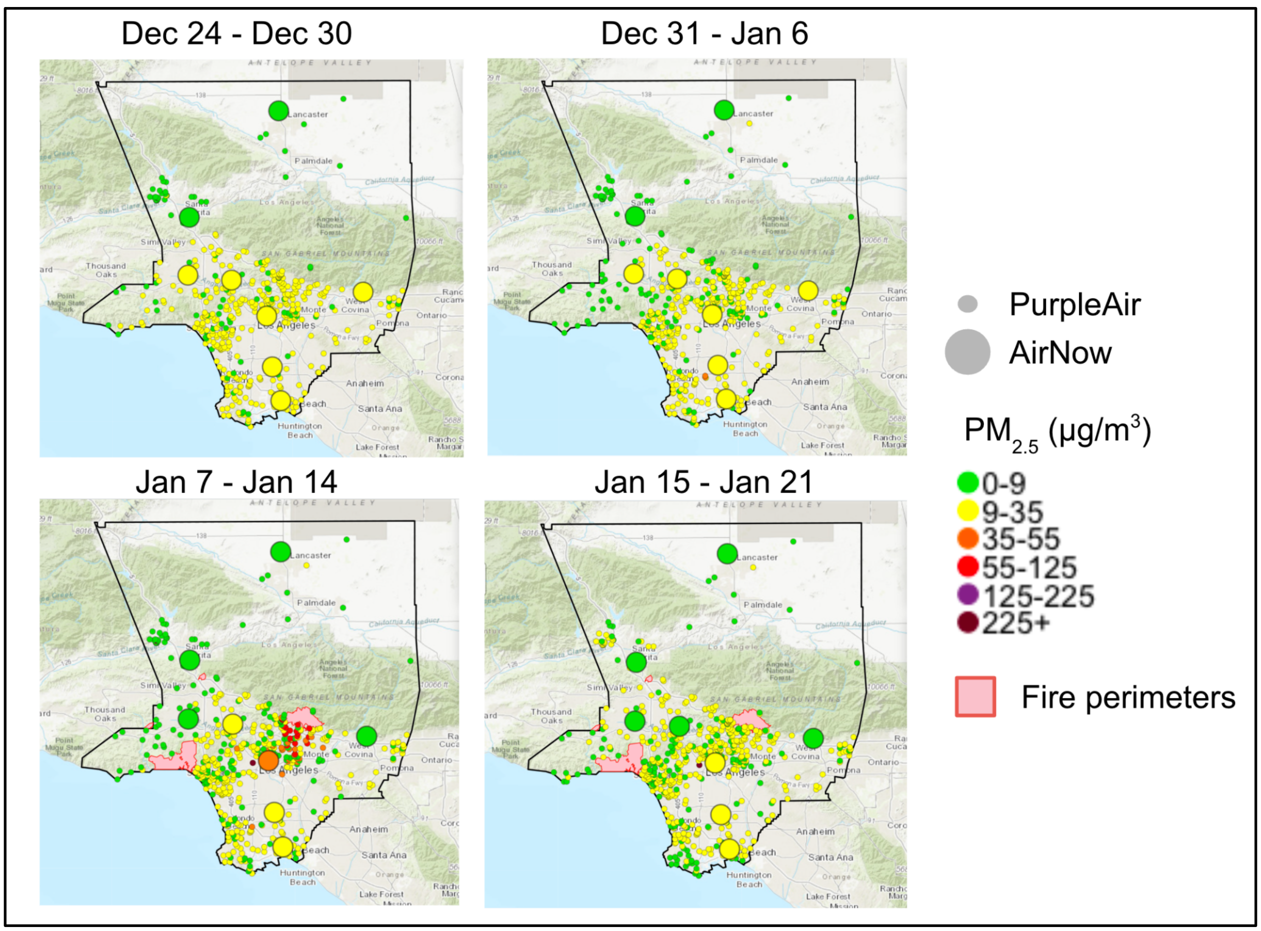

Figure S1. Daily average $PM_{2.5}$ concentration from AirNow and PurpleAir monitoring locations aggregated by week, including two weeks before fire ignition. Final fire perimeters are indicated in red. Concentration bins correspond to the $PM_{2.5}$ AQI cut points (i.e. Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy, Hazardous).

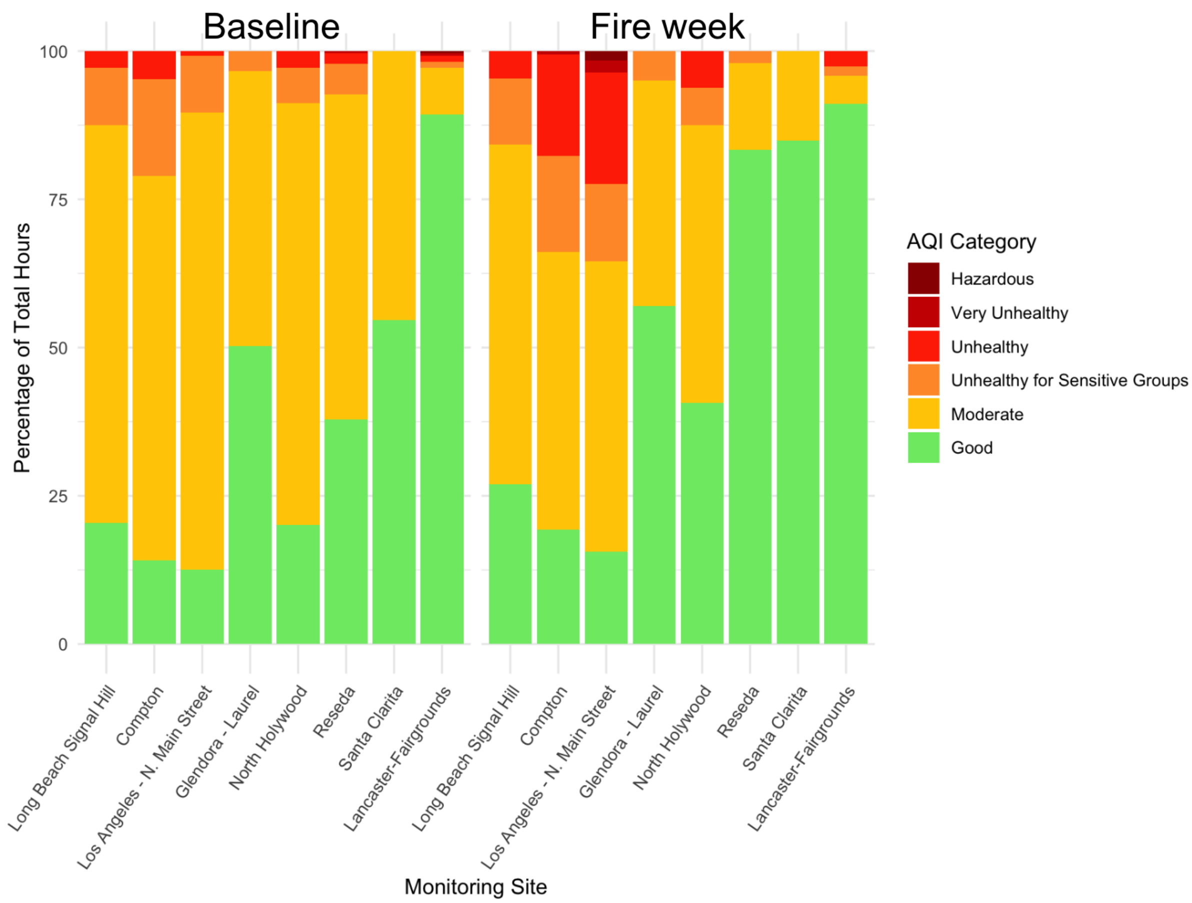

Figure S2. Percentage of total hours during the baseline (12-24-2024 to 1-6-2025 and 1-15-2025 to 1-21-2025) and fire-impacted period (1-7-2025 to 1-14-2025) when hourly $PM_{2.5}$ concentrations fell within each AQI category at each AirNow monitoring site.

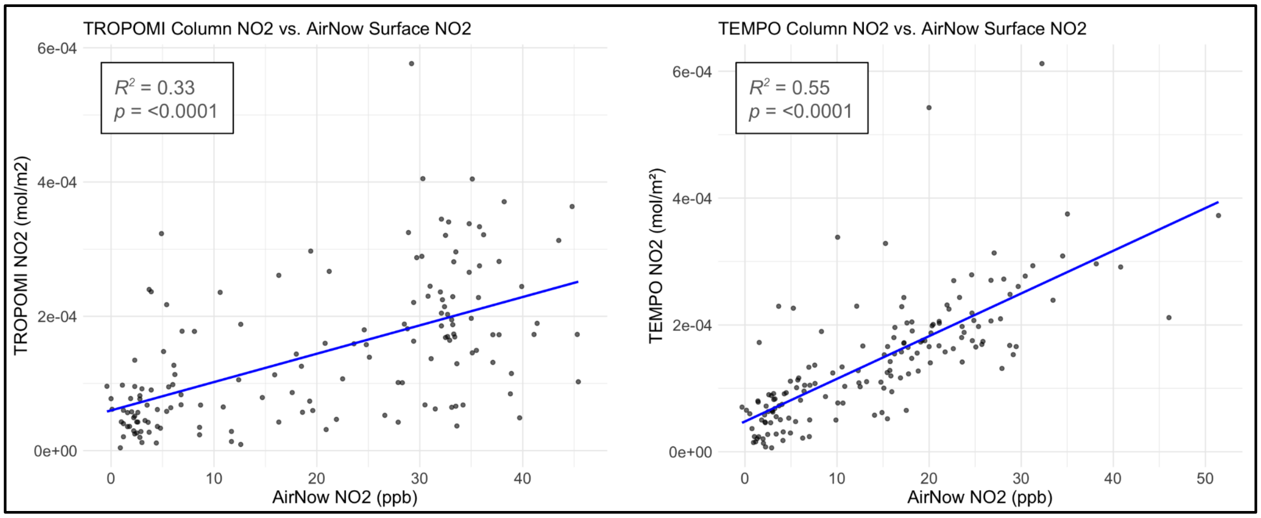

Figure S3. Scatter plots of NO_2 observations from TROPOMI (left) and TEMPO (right) versus AirNow surface NO_2 measurements from January 7-14, 2025.

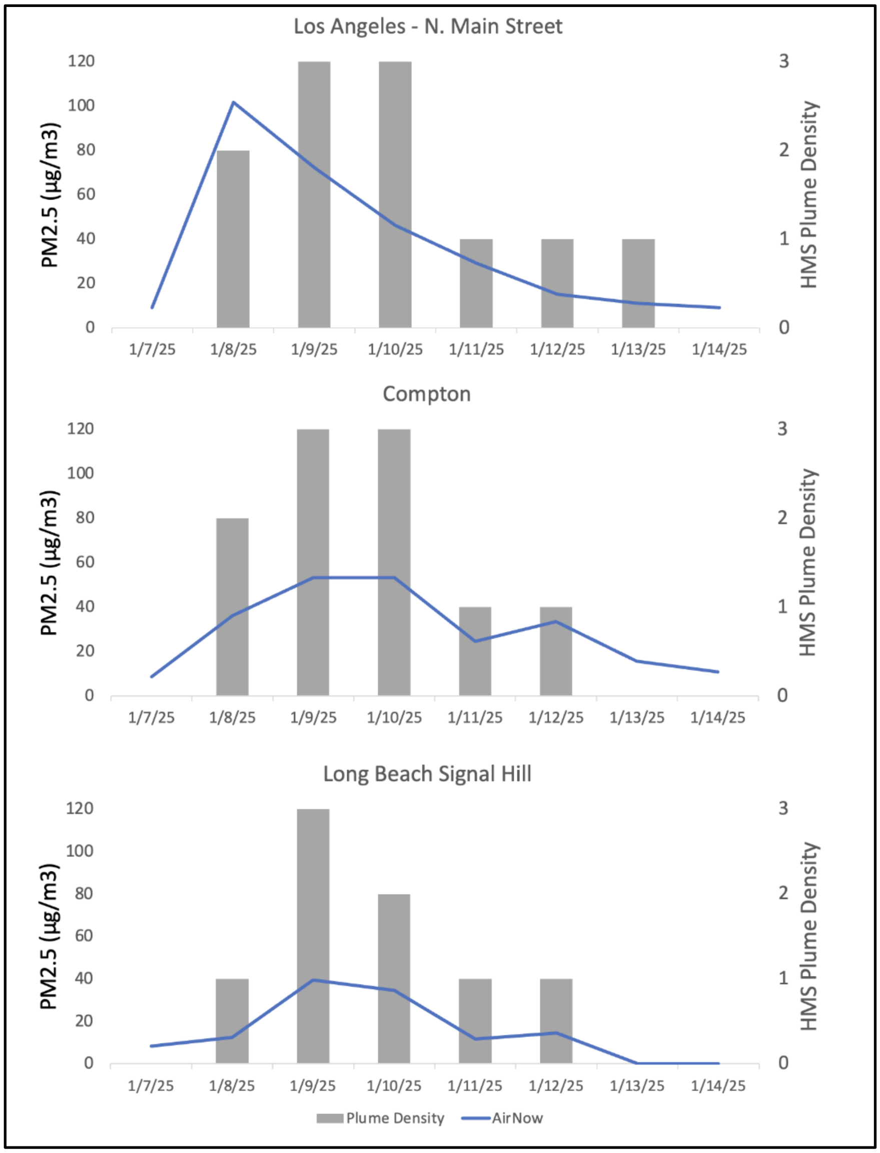

Figure S4. Time series of daily $PM_{2.5}$ concentration and HMS smoke plume density at 3 regulatory monitoring stations in LA County. For this figure, HMS plume densities are categorized as 0 = no plume, 1 = Light, 2 = Medium, and 3 = Heavy.