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Letter

Air Quality Impacts of the January 2025 Los Angeles Wildfires: Insights from Public Data Sources

Claire Schollaert,* Rachel Connolly, Lara Cushing, Michael Jerrett, Tianjia Liu, and Miriam Marlier

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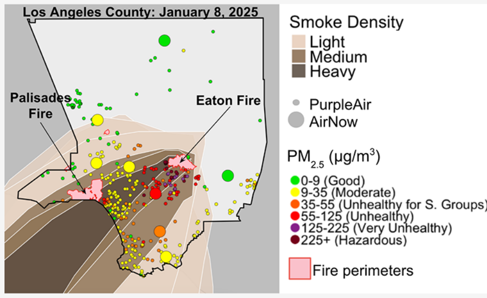
ABSTRACT: Smoke from the Los Angeles (LA) wildfires that started on January 7, 2025 caused severe air quality impacts across the region. Government agencies released guidance on assessing personal risk, pointing to publicly available data platforms that present information from monitoring networks and smoke plume outlines. Additional satellite-based products provide supporting 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 from regulatory monitoring stations, PurpleAir low-cost sensors, the TEMPO and TROPOMI satellite sensors, and Hazard Mapping System (HMS) Smoke Plumes during this multifire event. The most extreme air quality impacts were observed on January 8−9, particularly in the southern half of LA county, where daily average $PM_{2.5}$ concentrations at the downtown LA regulatory monitor reached 101.7 $\mu g/m^3$ and 52.3 $\mu g/m^3$ in Compton. On January 8th, 12 PurpleAir sensors located closer to burn areas exceeded daily $PM_{2.5}$ concentrations of 225 $\mu g/m^3$. While smoke impacts were largely consistent across all data sources, differences in the spatiotemporal, including vertical, 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, ground monitors, risk communication*

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]

Wildfire 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] Smoke exposure has been linked to respiratory-related mortality and morbidities, cardiovascular diseases, adverse pregnancy outcomes, and mental health impacts.[12,13] A preliminary study on the acute healthcare utilization effects of the LA fires found >35% increase in both cardiovascular and respiratory telehealth visits among exposed Kaiser Permanente patients within a week following the first ignition.[14]

When government agencies provide guidance for assessing risk and reducing smoke exposure, the first recommendation is typically to check the Air Quality Index (AQI), an U.S. Environmental Protection Agency (EPA) air pollution risk communication tool.[15−17] 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 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 data sets 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.[16,18] 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.[19] Additionally, satellite observations are available from agency websites, but often require advanced knowledge to interpret the information.

Winter meteorology in the LA Basin is often characterized by low wind speeds and temperature inversions, which can trap

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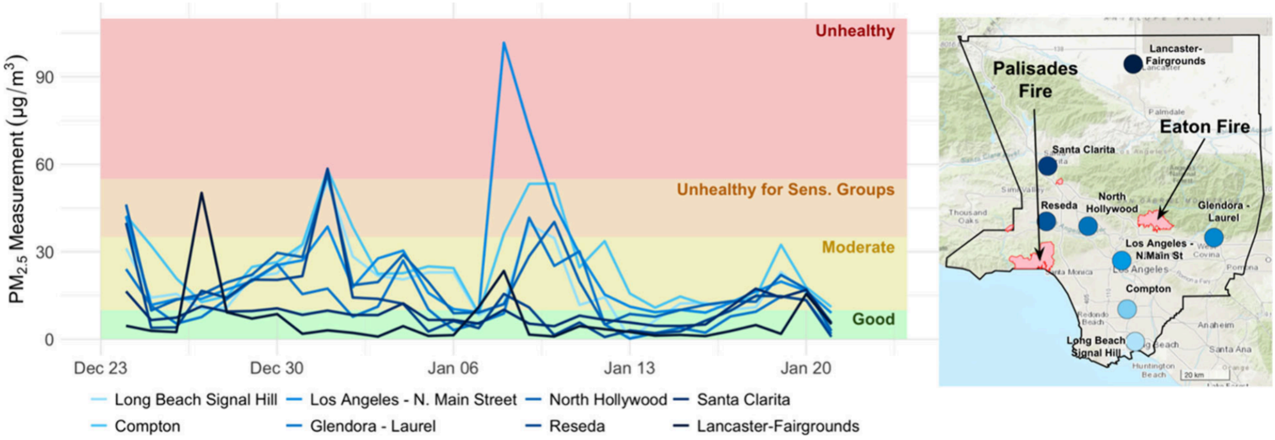

Figure 1. Daily average $PM_{2.5}$ concentrations from AirNow monitoring locations. Shading represents the concentration cutoffs for 'Good' (green), 'Moderate' (yellow), 'Unhealthy for Sensitive Groups' (orange), and 'Unhealthy' (red) AQI levels. The map on the right shows monitor locations with fire perimeters indicated in red from the National Interagency Fire Center.[38] The black boundary delineates LA county. 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.

air pollution from sources such as traffic, industrial activities, and residential heating near the surface (Figure S1).[20,21] Although stagnant atmospheric conditions are common in winter, Santa Ana wind events also occur most frequently during these months, increasing wildfire risk while enhancing atmospheric mixing and pollution dispersion.[22] Thus, while wind-driven winter wildfires can lead to a surge in smoke emissions, the same strong winds can transport these pollutants out over the Pacific Ocean.

As a result of a major Santa Ana wind event, the January 2025 LA wildfires introduced significant smoke emissions into the LA Basin. Providing the public with understandable and accurate pollution information is crucial to risk reduction and for informing future health impacts studies. Focusing on pollutants with information that was publicly available during the January 2025 fires, we compare $PM_{2.5}$, 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 the prefire period 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 prefire 'baseline period' (12−24−2024 to 1−6−2025), the 'fire period' (1−7−2025 to 1−14−2025), and the postfire smoldering period (1−15−2025 to 1−21−2025). 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. Negative values were removed under the default thresholds listed in the AirNow QC Criteria.[23] 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,[24,25] 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 the 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.[26]

We obtained satellite NO_2 measurements to compare to regulatory monitors. We downloaded tropospheric NO_2 data from the TROPOspheric Monitoring Instrument (TROPOMI) aboard the Sentinel-5 Precursor polar orbiting satellite from Google Earth Engine (GEE). TROPOMI collects global daily measurements of a range of pollutants in both tropospheric and stratospheric columns, including nitrogen dioxide (NO_2), formaldehyde (CH_2O), carbon monoxide (CO), ozone (O_3), methane (CH_4), and aerosols.[27,28] GEE regrids TROPOMI from Level 2 to Level 3, from a spatial resolution of 5.5×3.5 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 tropospheric column NO_2 from Tropospheric Emissions: Monitoring of Pollution (TEMPO), a geostationary satellite UV−visible spectrometer launched in April 2023 to provide high resolution pollutant observations over North America. TEMPO provides vertically integrated, hourly, 2.1×4.5 km^2 measurements of NO_2, O_3, CH_2O, and aerosols. We averaged the retrievals within the Level 3 product to estimate daytime average column NO_2. TEMPO observations are publicly available, but had provisional status at the time of publication.[29]

Meteorological Data. We obtained daily temperature, precipitation, and wind speed observations from 11 National Weather Service (NWS) stations across LA county. Observa-

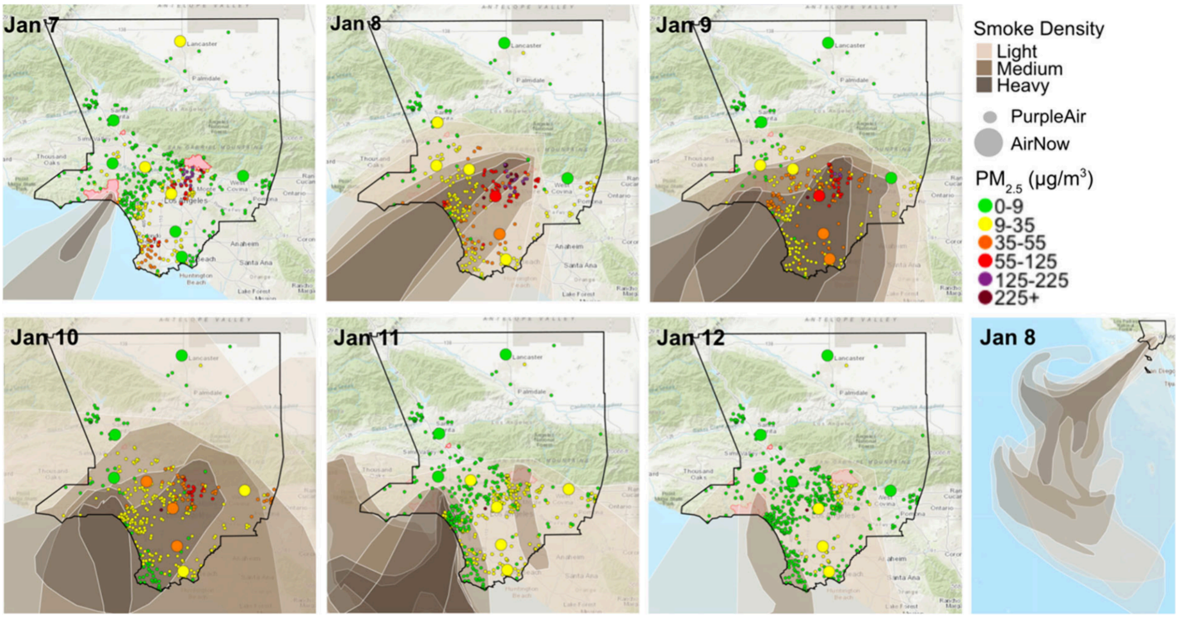

Figure 2. Daily HMS smoke plumes with average daily $PM_{2.5}$ concentrations from AirNow (large circles) and PurpleAir (small circles) from the first 6 days of the fire impacted period (January 7–12). Concentration bins correspond to the $PM_{2.5}$ AQI cutpoints (i.e., Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy, Hazardous). The map on the far right (bottom row) displays the full spatial extent of the smoke plume on January eighth. 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.

tions from each station were averaged to generate county-wide daily meteorological metrics.

Analysis. Following previous studies comparing air pollution across time periods, we used nonparametric Wilcoxon rank sum tests to assess differences in the distribution of daily $PM_{2.5}$ levels between the baseline, fire, and postfire periods at each regulatory monitoring location.[30−34] 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 relationship between average daytime ground measurements and the average column density of the grid cell colocated 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 characterized the relationships between HMS plume density, ground station $PM_{2.5}$ and satellite column NO_2 estimates using Kruskal–Wallis tests.

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 S2). New Year's Eve fell within our baseline period, during which the South Coast Air Quality Management District (SCAQMD) issued an air quality advisory due to fireworks.[35] SCAQMD issued a series of 'No Burn' advisories during the last week of December, due to low wind speeds and stagnant atmospheric conditions[36] (Figure S1). AQI levels of Moderate to Unhealthy were observed during the baseline period for six of the eight regulatory monitors (Figure 1).

High wind speeds started on January 7th, exceeding a daily county-wide average of 6 m/s and max 5-s wind speed of 37 m/s at the Burbank Airport station (Figure S1). With the ignition and intensification of the Palisades and Eaton fires, $PM_{2.5}$ concentrations in southern LA County increased shortly after. Daily average $PM_{2.5}$ concentrations at the downtown LA regulatory monitors reached 101.7 $\mu g/m^3$ on January 8th and in Compton, reached 52.3 $\mu g/m^3$ on January 9th (Figure 1). Both hourly and daily average $PM_{2.5}$ concentrations during the fire period were higher than the baseline period in Compton and downtown LA (Figure S3); however, these differences were not statistically significant (Figure S3, Table S1). 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 week compared to baseline (Figure S4). 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 S4). 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 average daily concentrations >300 $\mu g/m^3$, while 10 additional sensors, ranging from ∼ 0.5–7.5 km from fire, exceeded 225 $\mu g/m^3$ (Hazardous AQI) (Figure S3).[37]

Smoke Plumes. HMS plumes highlight the dynamic nature of smoke transport (Figure 2). The first satellite detections of smoke from the Palisades Fire show the plume extending over the Pacific Ocean, 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

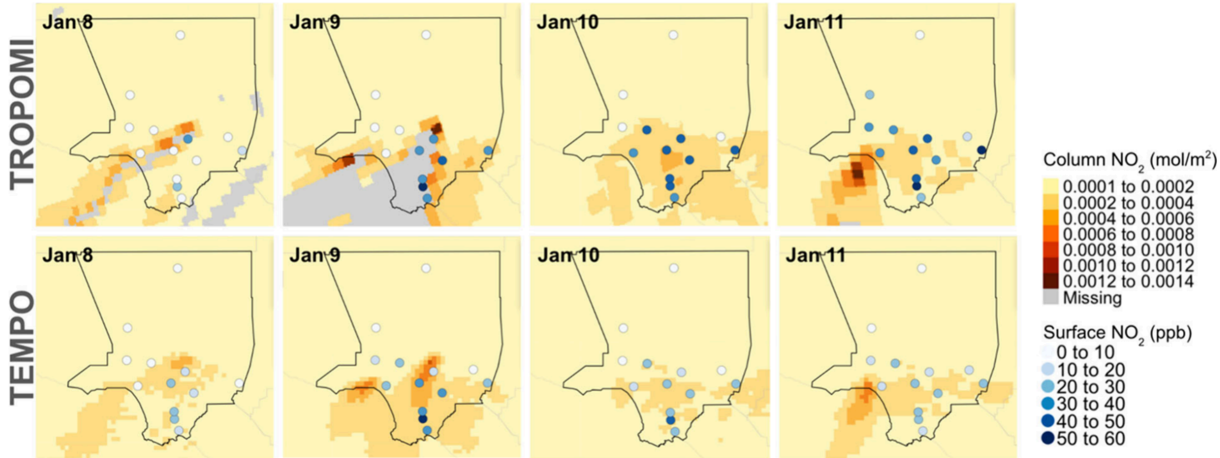

Figure 3. Daily tropospheric NO_2 vertical column number density from TROPOMI (top row) and average tropospheric TEMPO NO_2 (bottom row) from a subset of days during the fire period (January eighth-11th). Surface NO_2 concentrations from regulatory ground monitors on the top row reflect the hourly measurement 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).

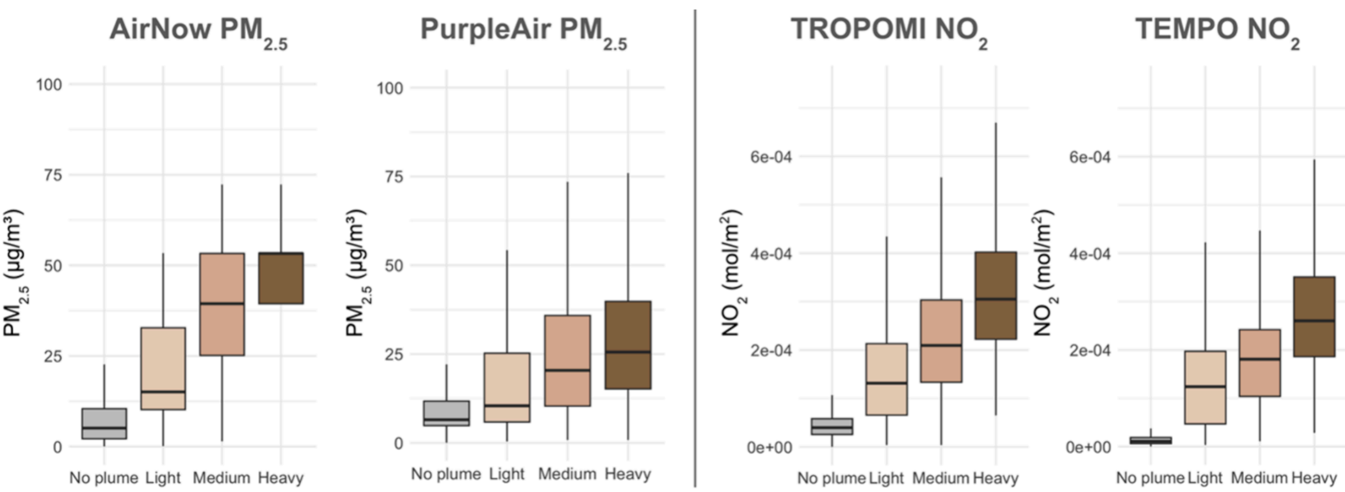

Figure 4. Box plots of daily $PM_{2.5}$ from AirNow and PurpleAir and NO_2 from TROPOMI and TEMPO in relation to HMS smoke plume density. Differences in pollutant concentrations across HMS smoke density categories were statistically significant in both monitor-based $PM_{2.5}$ and satellite-based NO_2 observations (Kruskal–Wallis H-test: AirNow $PM_{2.5}$: H(3) = 105, p < 2.2e-16, PurpleAir $PM_{2.5}$: H(3) = 3079, p < 2.2e-16, TROPOMI NO_2: H(3) = 127467, p < $_2$.2e-16), TROPOMI NO_2: H(3) = 47256, p < 2.2e-16).

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.

NO_2. Ground stations and other satellites measure additional pollutants, including NO_2, which varies in its correlation with ground $PM_{2.5}$ measurements depending on the station location and day following fire ignition (Figure S5). Figure 3 shows vertical column NO_2 from TROPOMI and TEMPO for 4 days postignition. 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 ninth (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. While county-level daily mean NO_2 concentrations measured at ground stations were not higher during the fire week (17.9 vs 24.4 ppb at baseline period), five southern stations, all under high density HMS smoke plumes, had daily averages exceeding 31 ppb daily averages on January 9th, with Long Beach reaching 51 ppb (28% higher than average baseline at that station) (Figure S6).

We found moderate agreement between station concentrations and satellite column enhancements (TROPOMI R^2 = 0.33, daytime average TEMPO R^2 = 0.55, hourly TEMPO R^2 = 0.23 during the smoke-impacted period) (Figure S7, S8). Disagreements can occur when the smoke is aloft, which contribute to lower R^2 values. For example, while average daily NO_2 concentrations peaked on January 9th in Long Beach (51.4 ppb), as noted above, the maximum column NO_2 measurements from both sensors were located closer to the active fires. Hourly NO_2 concentrations on January 9th

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exceeded the 53 ppb hourly NAAQS standard for 12 hours in Long Beach.

Intercomparison of Air Pollution Estimates and HMS Smoke Plumes. Higher $PM_{2.5}$ concentrations generally corresponded with higher-density HMS smoke plumes, though this relationship is not always consistent (Figure 4, Figure S9). Heavier HMS smoke plumes also tended to align with higher column NO_2 measurements from TROPOMI and TEMPO (Figure 4). 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.[34,35]

Strengths, Limitations, and Implications for Risk Communication. Each data source provides unique insights into air quality during wildfires (Table S2). Regulatory monitors provide highly accurate and temporally resolved information but the network is sparse and the real-time data is considered preliminary. Low-cost sensors, while less accurate and not used for regulatory purposes, provide more spatial coverage, though there are known disparities in sensor distribution, with fewer sensors in disadvantaged communities.[39,40] 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 and sensors 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. For example, AQI on the Fire and Smoke map is based on 24-h averages, while users of the PurpleAir map can adjust the averaging period used to calculate AQI, but will see a 10 min average by default. 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 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, which can vary in their correlation depending on combustion phase, plume age, and atmospheric chemistry (Figure S6),[41−43] though broadening to the chemical composition of particulates and other pollutants is needed to fully understand the exposure and health risks.[44] This is particularly true given that NO_x from wildfires is known to rapidly convert to peroxyacetyl nitrate and other oxidized nitrogen species.[45,46] Formaldehyde measurements are also available from both TEMPO and TROPOMI and may be useful in evaluating fire impacts in future work. Additionally, future work should examine ozone impacts of this fire event, given the potential abundance of precursor species from both the fires burning through urban landscapes as well as urban sources of NO_x and VOCs. 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 in downtown LA and in Compton identified elevated lead and arsenic levels between January 7−11.[47] 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 subdaily extremes. Further meteorological analysis would also help to better understand the contributions of emissions sources vs meteorology to smoke impacts during wind-driven fire events. Finally, additional approaches can be incorporated in future work to determine if a smoke plume is aloft, including the use of $PM_{2.5}$ to carbon monoxide ratios from ground stations and modeling tools like HYSPLIT, which can simulate the vertical distribution of smoke plumes.[48]

Here we present ground and satellite-based data products that can be used to evaluate exposure risk in real or near-real time during smoke events. While ground-based regulatory and low-cost sensor networks are most commonly cited in public health guidance, additional monitors are needed to improve spatial coverage. Satellite observations can also improve the spatial resolution of smoke information and provide the public with a more comprehensive understanding of exposure. From HMS plumes, which are already accessible in the Fire and Smoke Map, to observations from TROPOMI and TEMPO, satellite data sources can address spatial limitations in the ground monitoring networks; however, they are not always readily accessible to the public in their current form. Improved integration of these satellite data sets into user-friendly publicly available platforms is needed. Increased communications regarding the role of meteorological conditions during smoke events may also improve risk communication. Agencies and researchers need to continuously assess and improve public access to these data sources, taking steps to incorporate them into commonly used platforms like the Fire and Smoke Map or others. Checking local air quality conditions is the first step cited in almost every smoke-related public health communication, making it crucial that the public has access to this information from both ground-based and satellite-based sources.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.estlett.5c00486.

> Site-specific ground station summary statistics, overview table of data sources, times series of meteorological conditions, ground station $PM_{2.5}$ vs NO_2 time series, map of 1 day ground NO_2 and HMS plumes, ground NO_2 vs satellite NO_2 comparison, and HMS plumes vs site-specific ground $PM_{2.5}$ concentrations (PDF)

AUTHOR INFORMATION

Corresponding Author

Claire Schollaert − *Department of Environmental Health Sciences, UCLA Fielding School of Public Health, Los Angeles, California 90095, United States;* orcid.org/0000-0002-5046-0414; Email: cschollaert@ucla.edu

Authors

Rachel Connolly − *UCLA Center for Healthy Climate Solutions, UCLA Fielding School of Public Health, Los Angeles, California 90095, United States; UCLA Luskin Center for Innovation, Los Angeles, California 90095, United States;* orcid.org/0000-0002-0728-1779

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Lara Cushing − *Department of Environmental Health Sciences, UCLA Fielding School of Public Health, Los Angeles, California 90095, United States;* orcid.org/0000-0003-0640-6450

Michael Jerrett − *Department of Environmental Health Sciences, UCLA Fielding School of Public Health, Los Angeles, California 90095, United States*

Tianjia Liu − *Department of Geography, University of British Columbia, Vancouver, BC V6T 1Z2, Canada;* orcid.org/0000-0003-3129-0154

Miriam Marlier − *Department of Environmental Health Sciences, UCLA Fielding School of Public Health, Los Angeles, California 90095, United States;* orcid.org/0000-0001-9333-8411

Complete contact information is available at:
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Notes

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