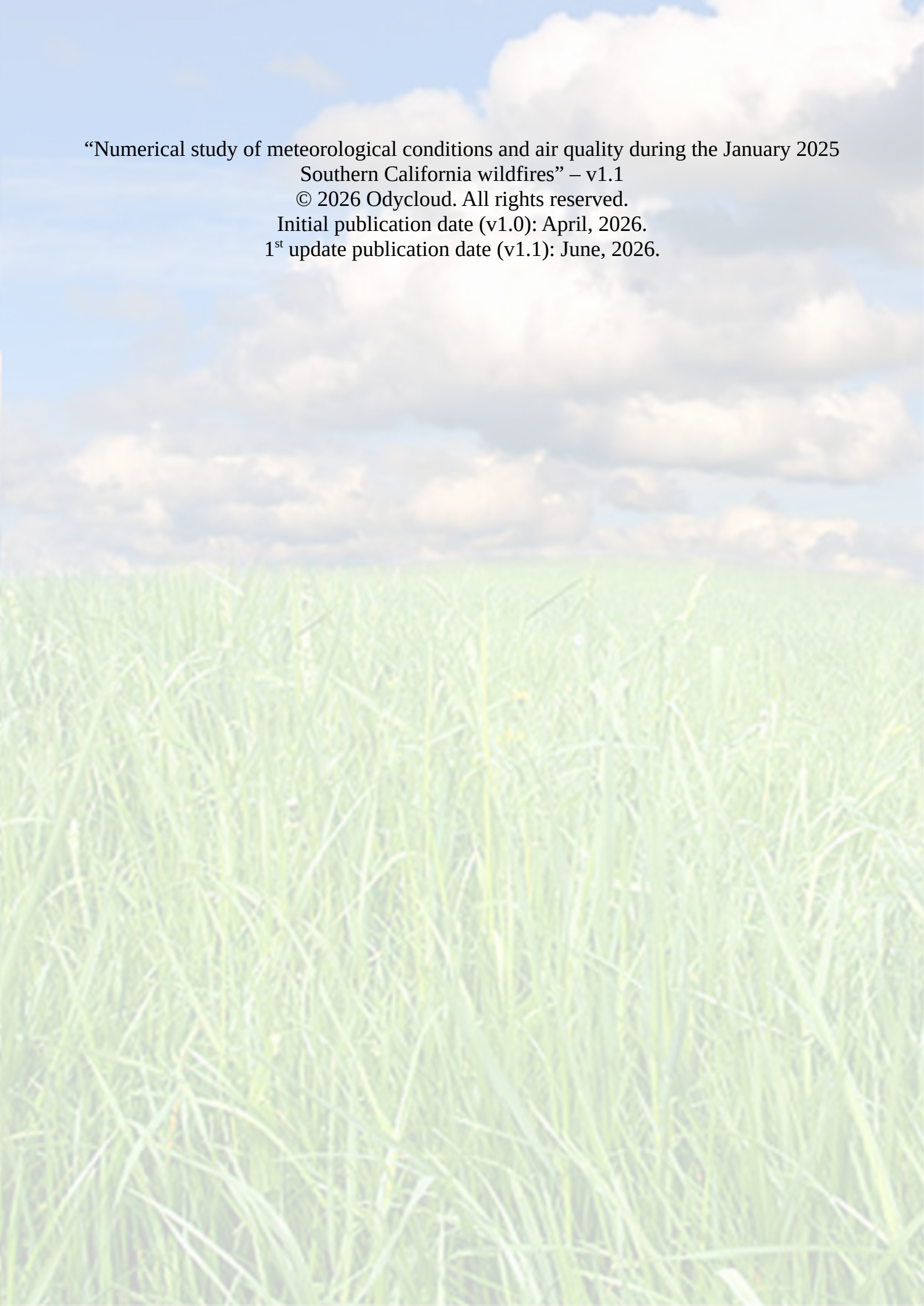


**Numerical study of
meteorological conditions and
air quality during the January
2025 Southern California
wildfires**

June, 2026



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Numerical study of meteorological conditions and air quality during the January 2025 Southern California wildfires

In January of 2025, meteorological conditions in the Los Angeles metropolitan area caused several wildfires to quickly spread and have catastrophic consequences. The two main fires known as the Palisades and Eaton Fires ignited on January 7 burning an official estimate of 23,448 and 14,021 acres, respectively, but several other minor fires broke out on this day and the following ones. The most direct consequences of these fires were the loss of 32 human lives plus several tens of billions in property damages still being evaluated. In addition to these losses, air quality reached hazardous levels in highly populated areas, which is suspected to have increased health conditions and mortality rates in the weeks and months following this tragedy. This numerical study systematically reassesses the meteorological conditions during these days, the intensity and emission rates from the wildfires, and their impact on air quality. The identification of the location, intensity, and emission rates for each wildfire utilizes the FINNV2.5 fire inventory. The study assesses meteorological conditions considering the urban environment affected by the fires, and using two forecasting datasets (GFS & NAM) and two reanalysis datasets (MERRA2 & ERA5). The latter results in a statistically closer agreement with observational data and are used as the meteorological background to compute the plumes caused by the wildfires. Evaluation of burnt acreage from the inventory returns a figure slightly higher than the official CAL FIRE's estimate, which is attributed to other minor fires detected by satellite measurements. Air quality simulations use EPA's CMAQ to model the transport and chemical reactions of the emitted airborne pollutants. The results from the simulations serve to assess several species concentration and AQI levels in the Los Angeles county from January 6 to January 15. The numerical predictions agree with observational measurements showing that the intensity and timing of peak particulate matter concentration depended on the relative location to the fires. Furthermore, the numerical results show the Eaton Fire to be mainly responsible for air quality deterioration in the most populated Los Angeles neighborhoods, whereas the Palisades Fire that burned almost twice the amount of vegetation to have had more limited impact and mostly concentrated in the southwestern neighborhoods near the shoreline. The simulations also capture significant increases in volatile organic compounds (VOCs) such as benzene, which might have caused an even more hazardous environment for high-risk populations than originally appraised.

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1. Introduction

In January of 2025, meteorological conditions in the Los Angeles metropolitan area caused several wildfires to quickly spread and have catastrophic consequences in material damage but, even more significantly, in human lives. The first estimate put the number of fatalities at 31. However, a recent study by Paglino et al. [1] using an excess mortality model estimated that this figure could climb as high as 440 due partly to the increase in lung and heart illnesses caused by worsening air pollution levels. Ebinger et al. [2] also found significant increases in pulmonary conditions (24%), cardiac episodes (46%), and laboratory blood abnormalities (118%) in the weeks following the fires. Yao et al. [3] conducted indoor and outdoor sampling at 22 residencies near the fires reporting high levels of volatile organic compounds (VOCs), specifically benzene, between January 8 and January 15. Their measurements continued for the next month when values went back to below the California Office of Environmental Health Hazard Assessment (OEHHA) health benchmark. Drawing a direct line between air quality and a mortality increase in any region is not easy. However, there is significant evidence that the January 2025 wildfires might have caused greater health issues in Southern California than originally assumed and that further air quality assessment should aid to understand this relationship.

Over the last few months, several organizations and agencies have completed studies on the January 2025 Southern California wildfires and published their findings. The California Department of Forestry and Fire Protection, hereafter referred to as CAL FIRE, provides data [4] about each incident in the state and related information to these fires was updated as of January 2026. Kerber et al. [5] recently published the first comprehensive study about the timeline of the wildfires after gathering an ample amount of evidence. CAL-FIRE [4] and Kerber et al. [5] reported that the 2 most damaging fires originated in the Palisades and Eaton areas starting on January 7 and burned approximately 23,448 and 14,021 acres, respectively. Over the following 2 days, other smaller fires burst in the Sunset (3 & 43 acres), Hurst (799 acres), Woodley (30 acres), Lidia (395 acres), Kenneth (1,052 acres) and Archer (19 acres) areas. An additional wildfire broke out on January 8 in Ventura county about 70 miles west of Los Angeles, which took another life and raised the official number of fatalities attributed to the wildfires to 32.

In addition to the timeline, it is paramount to understand the actions of first respondents and material damages. For example, the Los Angeles Fire Department drafted an after-action report [6] focused on the occurrence of the Sunset and Palisades Fires and their reaction to these fires. Kerber et al. [5] also stated that their initial report would be followed by another once focused on recommendations for first respondents. In addition to the human toll, wildfires are responsible for an increasing amount of material damage having a cascading effect on property values and insurance. Massomi [7] evaluated the impact on the insurance market of the increased risk of potential combinations of prolonged dry periods, high winds and wildfires causing costly damages. Even though the starting point for the study was the damage caused by the Palisades and Eaton fires, Massomi [7] concluded that the risk in Northern California has become almost as high as in Southern California. Kelly et al. [8] estimated the cost of the January 2025 Southern California wildfires in the \$40B and concluded that, due to the increasing frequency and cost of wildfire damage, the California insurance market should adopt a new model. Another work of interest was recently published by Lei et al. [9] who studied the dynamics of the wildfires by using satellite data with an approximate resolution of 14-km. They tracked the wildfires and CO columns using infrared and microwave sounders. They also used ERA5 data to complement their observations and concluded that including these measurements could potentially enhance the accuracy of simulations including wildfires.

Wildfires are complex phenomena that not only burn ground and structures but also result in significant emissions of gases and aerosols into the atmosphere. An important conclusion from observational data -notably from satellite information- during the last decades is that wildfires exhibit a wide variety of behaviors with many of them reaching well above the planetary boundary layer (PBL). Based on these observations, Fromm et al. [9] classified wildfires depending on fire power and amount of water vapor condensed during the buoyant-driven process. Dry smoke plumes usually stay within the PBL and, because they are the product of relatively weak wildfires, they barely contain if any water droplets. Pyrocumulus fires result from higher intensity wildfires with their physics being driven by water condensation; the final result is higher plume heights and whether they reach the free troposphere or stay

within the PBL depends on atmospheric conditions such as stratification strength or vapor content. The last category is pyrocumulonimbus fires, which represent a very small fraction of wildfires. In this type, the initial heat release is so potent that the plume reaches the stratosphere and ice particles are found at the highest plume elevations.

The present study seeks to numerically evaluate how these complex elements -meteorological phenomena, wildfire dynamics and transport- interacted in Southern California resulting in wildfire spread and hazardous air quality conditions.

2. Numerical approach

2.1. Background

In a similar fashion to how wildfires are driven by several physical phenomena, their numerical modeling can follow several approaches depending on the necessary simplifications to tackle the problem but, more importantly, on the final objective of the simulations. When the latter is the evaluation or prediction of air quality, the most advanced approach is the combination of a plume model with Chemical Transport Models (CTM) simulations. The latter compute chemical and transport phenomena, which dictate the wind-driven dispersion of airborne pollutants. One key step in formulating a plume model is the evaluation of plume height, which dictates not only hydrodynamics but also the emission distribution for the different species and pollutants. Early analytical models predicting plume height date back to the 1990s. Paugam et al. [10] present a thorough review of the different approaches and discerned between empirical, deterministic, and statistical models. The first provide poor accuracy, where the third type are still under development and their implementation into CTM simulations is still mostly untested. Among the deterministic type, Paugam et al. [10] discusses 3 parameterization models: (1) the plume is calculated based on a 1D cloud-resolving discretization, which requires the solution to vertical momentum, energy, and continuity for the water phase (Freitas et al. [11]); (2) use of an eddy diffusivity/mass flux scheme (Rio et al. [12]) where wildfire characteristics are not explicitly evaluated, but their impact is factored in through a subgrid term; (3) evaluation of wildfire characteristics through a combination of energy balance and dimensional analysis. The most commonly used model in the latter category is Sofiev's scheme [13, 14], which evaluates plume height as a function of Fire Radiative Power (FRP)

and atmospheric conditions. Moisseeva and Stull [15] proposed an alternative approach by assuming that the plume achieves a stable capping inversion state and closing out the model with the aid of their own synthetic LES simulations.

Implementations of plume models into CTM schemes are still scarce. Early simulations using this approach include the studies of Menut and coworkers who modeled Central Africa and its West Coast [16], and France during the summer of 2022 [17]. They used WRF with resolutions of 60 and 15 km, respectively, to drive CHIMERE. This code modeled the suspended phases as a mix of gaseous tracers plus 10 aerosols and used Sofiev's scheme to evaluate wildfire plumes. These authors noticed sensible increases in pollutants and particulate matter concentrations due to the wildfires. Li et al. [18] used EPA's Community Multiscale Air Quality (CMAQ) Model [19] to compare the performance of 3 different plume models in the prediction of PM_{2.5} exceedance during the summer of 2020 in the western U.S. The 3 tested models were the Briggs, Freitas, and Sofiev and their performance varied depending on wildfire characteristics and humidity. Li et al. [18] also noticed higher overall dispersion rates for higher plume heights. Puoyaei et al. [20] used the Geophysical Fluid Dynamics Laboratory's Atmospheric Model (AMv4.0) to model the entire globe and assessed the results in 8 regions commonly suffering from extreme wildfires; the plumes were evaluated mostly with Sofiev's scheme. Lu et al. [21] incorporated Freitas' scheme into D.O.E.'s Energy Exascale Earth System Model (E3SMv1) also covering the globe. Ke et al. [22] used the same framework focusing on pyrocumulonimbus fires. Both works [21, 22] outlined the need to include plume height to ensure accurate global results. June et al. [23] used GEOS-Chem-TOMAS to perform global simulations and studied how radiative properties change due to the impact of wildfires, and how this dependency is affected by plume height.

2.2. Plume models

Two models are used to evaluate plume heights: (i) Sofiev's scheme; (ii) a novel hybrid scheme that seeks to improve the prediction of large fires. Sofiev et al. [13] derived its scheme using an energy balance and finding the plume height as the point where the energy excess density curve exhibits a maximum. The main advantage of Sofiev's scheme is that the plume height (H_p) is expressed as a function of the Fire Radiative Power (FRP), the planetary

boundary layer thickness (H_{PBL}), and the Brunt-Väisälä frequency at the free troposphere (N_{FT}) according to:

$$H_p = \alpha H_{PBL} + \beta \left(\frac{FRP}{FRP_0} \right)^\gamma \exp\left(-\delta \frac{N_{FT}^2}{N_0^2}\right) \quad (1)$$

Here, FRP_0 ($10^6 W$) and N_0^2 ($2.5e^{-4} s^{-2}$) are the reference FRP and square of the Brunt-Väisälä frequency, respectively. The coefficients α , β , γ and δ depend on the chosen procedure. Although it is feasible to use eq. (1) as a single step, Sofiev et al. [13] recommend a two-step procedure in order to improve accuracy. The first step, which uses an initial parameter set of $\alpha=0.15$, $\beta=102$ m, $\gamma=0.49$, $\delta=0.0$, seeks to obtain a preliminary plume height estimation that can be compared versus the thickness of the PBL. Then, the initial estimate is re-evaluated depending on whether the plume reaches the free troposphere. For plumes within the PBL the parameters are $\alpha=0.24$, $\beta=170$ m, $\gamma=0.35$ and $\delta=0.6$ whereas when the plume reaches the free troposphere, the preferred parameter switch to $\alpha=0.93$, $\beta=298$ m, $\gamma=0.13$ and $\delta=0.7$. In spite of these refinements, the Sofiev's scheme can still be an underpredictor for large fires as the latter gamma coefficient effectively caps out the dependency of plume height on FRP.

Here, and in order to have an alternative plume height prediction not capped out by the PBL thickness, a novel model is introduced to aid the evaluation of large fires. The starting point is the energy balance proposed by Moiseeva and Stull [15], which expresses the specific potential energy of the plume caused by smoke penetration as a fraction of the specific kinetic energy driven by buoyancy phenomena.

$$e_p = k_1 e_k \quad (2)$$

Moiseeva and Stull [15] express the specific potential energy as a function of gravity acceleration (g), potential temperature (θ), the previously introduced plume height, and a reference height (H_s):

$$e_p = g \left(\frac{\theta_p - \theta_s}{\theta_s} \right) (H_p - H_s) \quad (3)$$

Here, the reference point for height and potential temperature is taken at the top of the PBL. The specific kinetic energy is a function of a velocity scale (w_p) characterizing the plume buoyant velocity:

$$e_k = 0.5 (w_p)^2 \quad (4)$$

Moiseeva and Stull [15] express this characteristic velocity as a function of the kinematic heat flux integrated along the fireline depth (ι):

$$\iota = w_p z_i \theta' \quad (5a)$$

Moiseeva and Stull [15] quantify the value for this expression from their LES synthetic simulations. However, evaluating this expression from satellite information is not feasible. Instead, we propose an alternative expression by combining dimensional analysis with the assumption that the kinetic energy is a function of the rate of heat released by the wildfire. After operating, an alternative expression for the kinematic heat flux integrated along the fireline depth turns into:

$$\iota = \sqrt[4]{\frac{FRP A_f^3}{\epsilon}} \left(\frac{1}{t_0} \right), \quad (5b)$$

where ϵ is the Stefan-Boltzmann constant and t_0 is a characteristic time associated with the plume. The last step proposed by Moiseeva and Stull [15] is to substitute these expressions in eq. (2) and, after operating, the plume height becomes an implicit function:

$$H_p - H_s = K_{pl} \sqrt{\left[\frac{\theta_{ref}(H_p - H_s)}{g(\theta_p - \theta_s)} \right] \left[\frac{g \iota (\theta_p - \theta_s)}{\theta_s (H_p - H_s)} \right]^{(1/3)}} \quad (6)$$

In eq. (6), the square root term is a characteristic time and the bracketed expression represents a characteristic velocity scale. Equation (6) is implicit in that the plume height is in both sides of the equation through eq. (5a), and require an iterative method for its solution. When eq. (5a) is substituted with eq. (5b), there is an extra implicitness as the characteristic time needed to evaluate the expression is taken as square root included in eq. (6). However, this formulation has the advantage that all parameters can be evaluated from either satellite measurements or from the WRF output.

The practical implementation of using eq. (5b) instead of eq. (5a) these expression is with the aid of a hybrid scheme. The hybrid scheme also uses eq. (1) to perform a first estimate of the plume height, which is compare versus the PBL thickness every hour.

When the plume stays within the PBL, the height is still evaluated according to Sofiev's scheme. However, and when the plume reaches the free troposphere, its height and the characteristic time are calculated by using an iterative procedure to simultaneously solve equations (5b) and (6).

2.3 Numerical methodology

The numerical methodology involves a three-step process combining some of the software packages listed in annex I to sequentially generate meteorological data, emission rates, and air quality predictions.

The first set of computations generate meteorological results using the Advanced Research Weather Forecasting Model (WRF) [24], which performs mesoscale weather predictions. WRF is a well-established software for both operational purposes and as a research tool. The results from the WRF simulations are needed as the background to estimate plume characteristics and compute transport phenomena.

The second step involves the computation of emission rates for the different species involved in the CTM computations. Here, the consideration is that wildfire emissions are evaluated independently from regular emissions, and the procedure is therefore divided into two sub-steps. The first sub-step computes anthropogenic emissions from inventories and standard biogenic emissions. As the availability of anthropogenic inventories lag 3 or 4 years, this work uses interpolated averages from COPERNICUS inventories [25]. This introduces a degree of uncertainty but the final results can be revised at a later date when the final inventories become available. In the second sub-step, INCENDII reads the previously generated WRF output file, identifies the wildfire locations, evaluates their characteristics, and generates CMAQ-ready emission streams. When performing the CTM simulations, the air composition depends on the interaction between these stream sources and the ambient air along with any chemical reaction taking place. In areas mostly affected by the wildfires, which are the main target of the present work, air composition depends mostly on wildfire emissions; however, the final results in areas weakly affected by wildfires are likely to exhibit weaker performance due to the uncertainty in the quantification of the anthropogenic emissions.

The third group of simulations involves the completion of the air quality simulations with CMAQ [19], which represents state-of-the-art software in CTM modeling and the computation of airborne pollutants. Unlike in previous generations of CTM software, where the most common approach was to use a Lagrangian perspective to compute pollutant dynamics, CMAQ uses an Eulerian description solving the transport equations for gases

and aerosols. Additionally, chemical reactions are accounted for through the formulation of a chemical mechanism. CMAQ has used several chemical mechanisms throughout its different versions. As of 2026, the recommended mechanisms are Carbon Bond and the Community Regional Atmospheric Chemistry Mechanism or CRACMM [26]. The former has been the most commonly used mechanism over the last few years, and it is currently in version 6 (CB6), which is a slight upgrade of the previous version (CB5). CRACMM, which is now in version 2, is an upgrade to the Regional Atmospheric Chemistry Mechanism (RACM) and is anticipated to be the preferred choice for the rest of the decade. CMAQ requires a meteorological set as input. Although it is technically feasible to use the output of any scientific meteorological software, most current computations use WRF results with future simulations expected to begin a transition towards MPAS-CMAQ [27] in upcoming years. The first step towards performing any CMAQ computations is to pre-process the WRF results with the (MCIP) module. In this step, it is feasible to slightly resize the WRF domain by trimming the edges where the results are usually less accurate. Before running CMAQ, it is also necessary to generate initial and boundary conditions, which is usually accomplished with BCON/ICON. The results from these simulation facilitate the assessment of air quality in the area affected by the wildfires and any variation in meteorological predictions caused by a high concentration of airborne pollutants. All the tasks have been performed using AWS infrastructure. The computations themselves have been performed on EC2 instances powered by Graviton4 processors. This choice was made based on balancing cost and performance (i.e. wall times), and facilitate the selection of the number of cores and memory depending on the size and requirement of each simulation. The other AWS service frequently used was S3 (Simple Storage Service) buckets to store and quickly transfer files to and from the instances. Another advantage of using AWS S3 buckets is that it is now much easier to transfer files or even entire buckets to other cloud service providers' storage systems such as Azure Blob Storage via AzCopy or AWS DataSync, Google Cloud Storage (GCS) via the gcloud CLI or AWS DataSync, Oracle Cloud Infrastructure (OCI) Object Storage or others.

3. Meteorological simulations

The completion of the meteorological simulations involves the download of forecasting and reanalysis datasets, the generation of suitable data with the WRF Preprocessing System (WPS), and the completion of the simulations with the latest available version of WRF: v4.7. These codes were compiled and optimized with OpenMPI v5.0.6 for AWS Graviton4 instances running on Ubuntu 24.04. In order to perform an assessment of the meteorological results, the initial simulations use two forecasting and two reanalysis datasets. The former are the North-America mesoscale model (NAM) and the Global Forecast System (GFS) being both generated by NOAA. These datasets include several products with different resolutions and domains; the choices include the smaller NAM domain with a 12 km resolution and GFS with a 0.5° resolution. The original intention was to also test RRFS data, which would have had the finest resolution at 3 km. However, this model is still in the prototype phase and was not run at the beginning of 2025 including the dates of interest. The two reanalysis datasets are the ERA5 model from the European Centre for Medium-Range Weather Forecasts (ECMWF) with a 0.25° resolution, and MERRA2 from the U.S. National Aeronautics and Space Administration (NASA) with a 0.625° by 0.5° resolution in the longitudinal and latitudinal directions, respectively. These two datasets use complex data assimilation procedures to improve reanalysis and are under active development. All these datasets are available from public AWS S3 buckets¹, which accelerates their download significantly.

The WRF simulations cover 11 1/2 days starting on January 5 and ending on January 16 at 12 UTC. The first day, January 5, is discarded and, due to the time difference of 8 hours between between UTC and PST, the spin-up time is essentially 32 hours. The last 4 hours do not factor in any statistical analysis. The present simulations do not use observational nudging, which could potentially decrease the errors quantified below. However, this action could mask any bias thus hindering future efforts focused on forecasting and analysis of hypothetical or worst-case scenarios. In order to accommodate the mesh and initialize WPS, the projection is set to Lambert Conformal Conical (LCC), which is the most

common projection for WRF simulations, particularly in mid latitudes. The center of the domain is placed at 34° 15' N and 118° 18' W, which is located in the Angeles National Forest near where the Eaton Fire originated and slightly northeast of Altadena. The grid uses a resolution of 1 km in both north-south and west-east directions encompassing 39,644 km². The number of eta levels is 41 with the number of vertical layers equaling 40; the time-step is set to 5 seconds. As the domain covers the Los Angeles metropolitan area, the physics module was tuned to capture an urban environment.

The analysis of the results requires the identification of some reference locations within the computational domain to interpolate the results and complete the statistical analysis. The reference locations correspond to 12 stations belonging to the worldwide Integrated Surface Dataset (ISD) network. Table 1 lists the latitudes and longitudes for these stations.

Table 1. Latitudes and longitudes for the reference locations used to perform the statistical analysis. All locations belong to the Integrated Surface Dataset network.

	Station	Latitude	Longitude
St-1	Van Nuys A/P	34.21214°N	118.49146°W
St-2	Burbank/Pasadena A/P	34.19966°N	118.36543°W
St-3	Santa Monica A/P	34.02099°N	118.44712°W
St-4	LAX	33.93816°N	118.3866°W
St-5	Hawthorne A/P	33.92353°N	118.33291°W
St-6	Long Beach A/P	33.81177°N	118.14718°W
St-7	Santa Ana A/P	33.67975°N	117.86746°W
St-8	Riverside A/P	33.95282°N	117.43523°W
St-9	Ontario A/P	34.05314°N	117.57689°W
St-10	Edwards AFB	34.9°N	117.86667°W
St-11	Lancaster	34.74121°N	118.21255°W
St-12	Oxnard	34.20012°N	119.20417°W

Once the simulations complete, the outputs files are stored in private S3 buckets to facilitate any postprocessing task and the setup of the CMAQ simulations. Animations of the numerical results show how the Santa Ana (northeasterly) winds begin to pick up intensity in the early hours of January 7. By the time that the Palisades and Eaton Fires ignite on that day, the Santa Ana winds are strong enough to cause the wildfires to quickly spread and drag any airborne pollutant in the southwest direction. Figure 1a illustrates this dynamics by showing wind speed contours at 10 m above the ground from the ERA5 simulation on January 7 at 4 pm local time, when the Palisades Fire is already burning and the Eaton Fire

1 NAM, GFS, and ERA5 data are readily available to any AWS user; however, downloading MERRA2 data requires the acquisition of a temporal token and can only be downloaded from instances in the us-west-2 region.

is starting [5]. Figure 1 also shows horizontal velocity vectors every 5 km, the approximate locations for the Eaton and Palisades Fires, the minor fires, and the ISD network stations. Figure 1b shows the same items 24 hours later on January 8 when the winds have begun to slightly taper down but they are still strong enough to aid the spread of the wildfires.

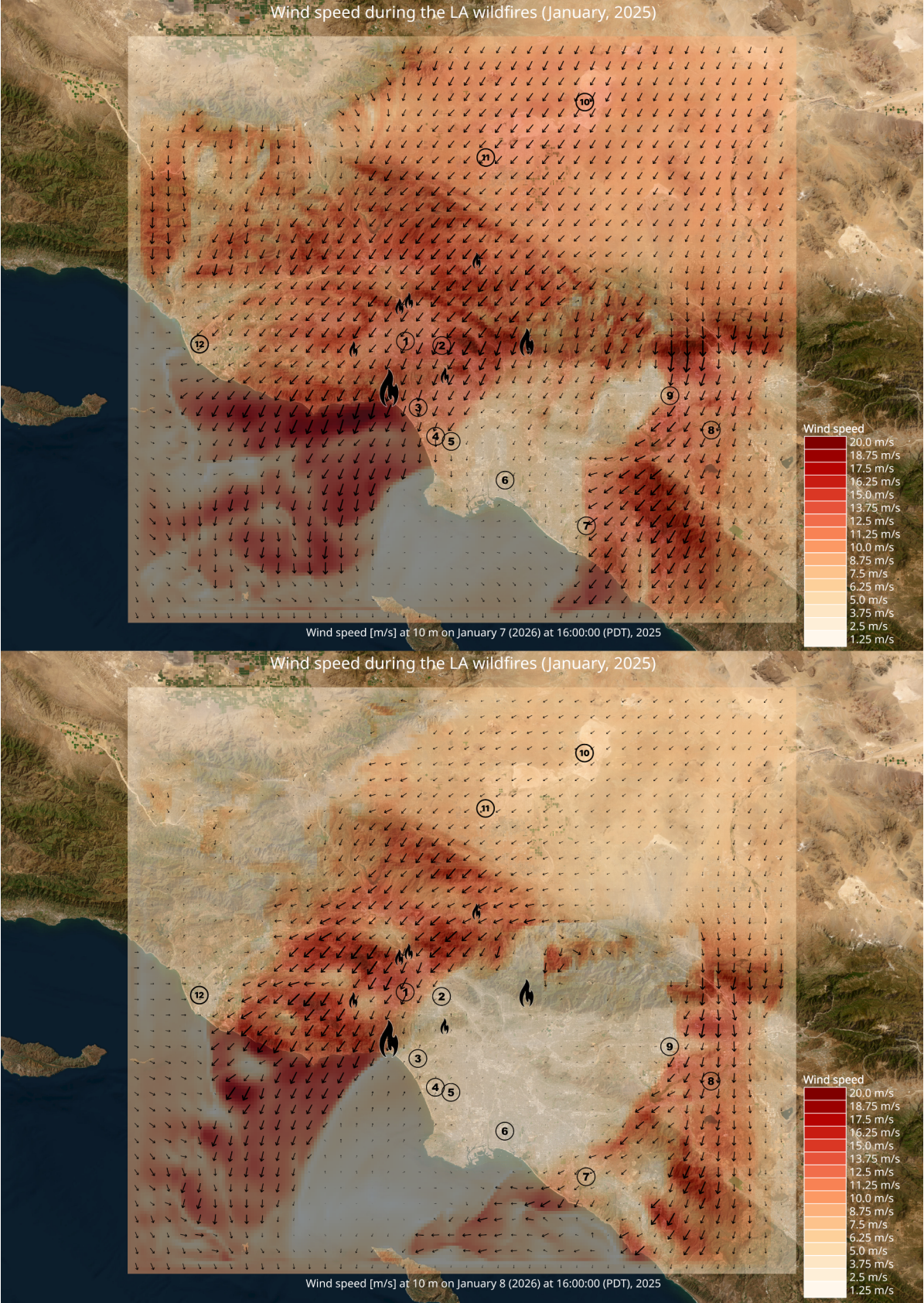


Figure 1. Wind vectors and wind speed contours on January 6 at 4 pm (PST). The figure also shows the locations of the wildfires and the meteorological stations.

To begin assessing the performance of the results using the different datasets, Figure 2 shows the hourly predictions versus the observational data for temperature and wind speed module. All temperature predictions capture the diurnal cycle but the ERA5 results are better at capturing the maxima and minima. MERRA2 overpredicts the lows as their soil temperatures exhibit lower magnitudes during the

nights. As commonly observed, the discrepancy for wind speed is higher partially because of computational restrictions but also because the uncertainty in measurements is larger than for temperature. All simulations slightly underestimate the highest intensity winds measured in the early hours of January 8, but the best performer is again the simulations using ERA5 data.

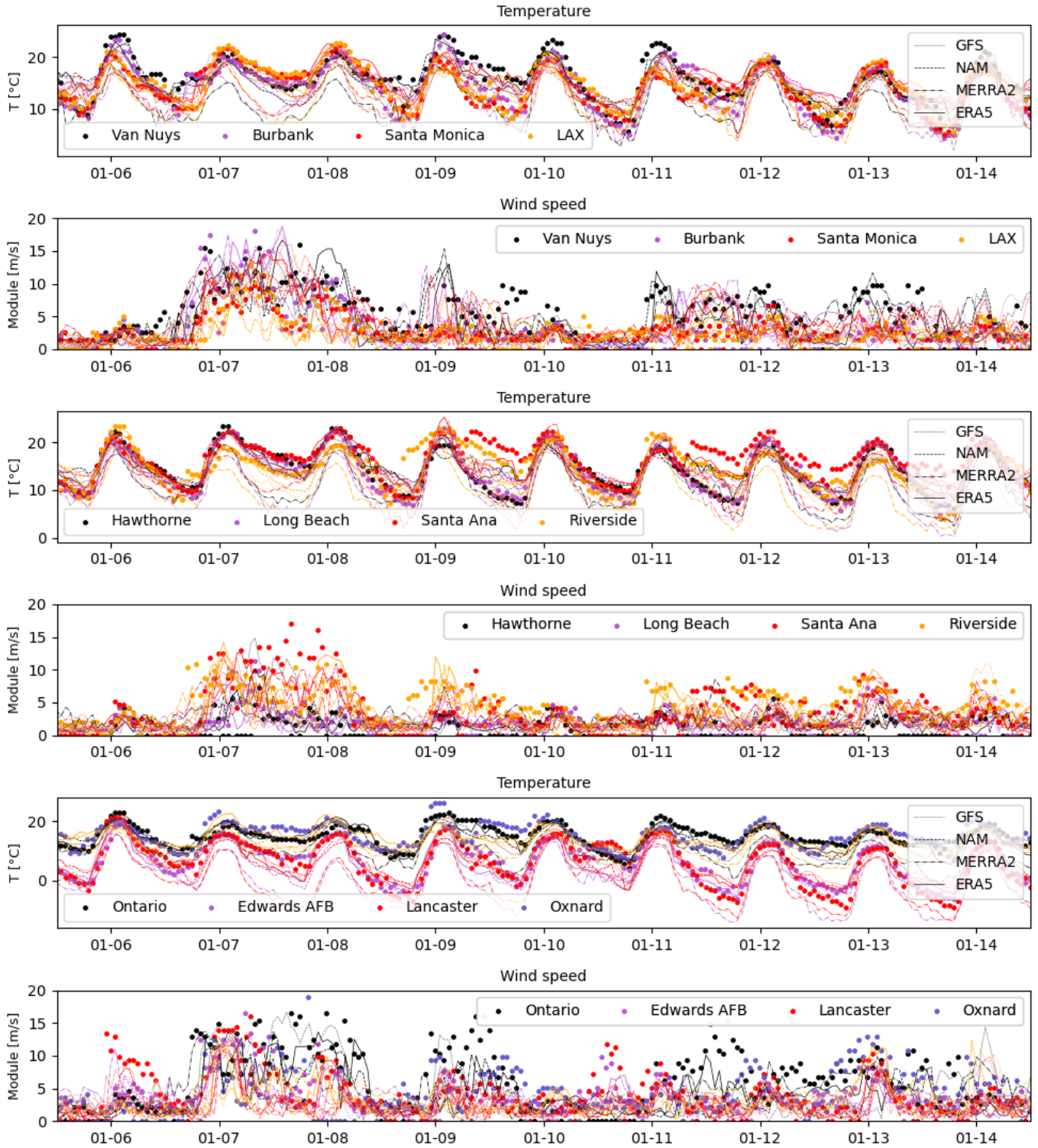


Figure 2. Observational measurements and hourly numerical predictions for temperature and wind speed at the 12 ISD stations.

In order to assess the statistical variation of the different datasets, Table 2 provides an overall summary of the results by quantifying Mean Bias Error (MBE) and Normalized Root Mean Square Error (NRMSE) for both temperature and wind speed. In general temperature predictions look closer

to the observed data and, as expected, the simulations with the ERA5 dataset result in more accurate results and are preferable for reanalysis versus the forecasting datasets (NAM & GFS). Hereafter, the assesment of wildfires and air quality computations use the ERA5 output results.

Table 2. Summary of the estimated Mean Bias Error (MBE) and Normalized Root Mean Square Error (NRMSE) for NAM, GFS, MERRA2 and ERA5 datasets.

	Temperature							
	MBE [°C]				NRMSE			
	NAM	GFS	MERRA2	ERA5	NAM	GFS	MERRA2	ERA5
Van Nuys A/P	0.815	1.500	4.666	0.242	13.328%	15.047%	27.354%	10.666%
Burbank/Pasadena A/P	-1.034	-0.360	2.498	-1.588	15.025%	13.663%	18.156%	13.818%
Santa Monica A/P	-1.195	-0.316	1.674	-1.320	16.213%	14.015%	18.908%	15.413%
LAX	-0.276	1.050	3.324	0.118	12.417%	11.761%	25.440%	11.429%
Hawthorne A/P	-0.588	0.800	3.491	-0.113	14.203%	10.313%	24.816%	12.015%
Long Beach A/P	-0.868	1.025	3.962	-0.284	14.014%	9.680%	24.296%	10.254%
Santa Ana A/P	1.406	2.957	4.083	1.265	19.991%	29.274%	36.114%	16.701%
Riverside A/P	1.148	1.420	5.456	0.253	15.627%	16.097%	32.444%	11.416%
Ontario A/P	0.760	1.351	4.969	0.829	12.471%	15.469%	32.554%	11.856%
Edwards AFB	2.172	0.805	7.605	1.511	13.921%	11.676%	31.813%	13.500%
Lancaster	0.248	-1.030	6.107	0.02	13.557%	11.914%	23.209%	11.985%
Oxnard	2.111	1.950	3.893	0.883	19.275%	18.100%	26.008%	14.670%
Average	0.395	0.929	4.311	0.151	15.003%	14.751%	26.812%	12.810%
	Wind speed							
	MBE [m/s]				NRMSE			
	NAM	GFS	MERRA2	ERA5	NAM	GFS	MERRA2	ERA5
Van Nuys A/P	0.619	1.657	0.082	0.838	19.594%	24.147%	19.840%	20.828%
Burbank/Pasadena A/P	-1.087	-0.570	-0.796	-1.099	16.257%	18.088%	18.970%	17.703%
Santa Monica A/P	-1.264	-0.989	-2.054	-1.117	23.993%	24.947%	28.596%	24.615%
LAX	0.183	0.625	-0.347	0.391	16.508%	16.265%	18.488%	15.145%
Hawthorne A/P	-0.905	-1.390	-1.75	-0.703	23.758%	38.525%	36.378%	24.991%
Long Beach A/P	-0.055	-0.193	-1.335	0.139	15.235%	16.011%	22.802%	15.252%
Santa Ana A/P	0.995	1.249	0.654	0.949	16.480%	19.946%	17.590%	15.297%
Riverside A/P	1.240	1.133	0.809	0.663	25.777%	28.867%	24.752%	26.571%
Ontario A/P	2.501	1.488	0.723	1.822	27.547%	29.338%	24.027%	23.925%
Edwards AFB	0.757	0.656	0.301	0.329	18.609%	17.557%	19.272%	14.859%
Lancaster	1.771	1.667	1.936	1.468	21.856%	19.971%	21.738%	19.101%
Oxnard	1.576	1.433	0.421	1.573	18.640%	20.475%	17.074%	19.042%
Average	0.528	0.506	-0.113	0.438	20.355%	22.844%	22.461%	19.777%

4. Assessment of wildfires and their characteristics (January 6-January 15)

The evaluation of wildfires in the area of study along with their characteristics is performed by combining data from the Fire INventory from NCAR (FINN) [28, 29] inventory with the WRF output file. FINN provides the location, general properties and base emission rates for open biomass burning on a daily basis by using measurements from MODIS and VIIRS satellite instruments. The new algorithm introduced in version 2.5 improves the accuracy of fire size estimates by aggregating adjacent fire detection data yielding a 1 km resolution. For modeling purposes, this is beneficial as the total number of identified fire locations is usually higher than those reported in other sources because large wildfires, such as the Palisades and Eaton Fires, have several loci captured by satellite imagery. This fact is beneficial for air quality simulations as it enhances accuracy at the time of locating emissions into the gridded mesh.

Here, the assessment of wildfires focus on the 10 days starting on January 6 and ending on January 15. Before describing more specific statistics, Table 3 lists a daily summary of the identified number of fires, burnt area and biomass based on FINNv2.5 data. Kerber et al. [5] reported the area burned by the Eaton and Palisades to be 23,448 and 14,021 acres plus another 2,611 acres burned by the smaller fires. Considering the fires identified by FINN between January 7 and January 10, the total burnt acreage is 46,266.5, which includes some smaller fires in the area between Victorville and Barstow. The timeline for burnt acreage also reflects on burnt biomass that -as shown in the Table 3 figures- peaked on January 8, but significant amounts of vegetation kept burning until January 11.

Table 3. Daily summary of the number of wildfires, burnt area in km² and acres, and burnt biomass in metric tonnes identified by FINNv2.5.

Date	Number of wildfires	Burnt area [km ²]	Burnt area [acres]	Burnt biomass [t]
January 6	13	0.98	241.7	262.4
January 7	33	8.67	2143.1	5814.5
January 8	179	102.86	25418.3	71179.2
January 9	110	48.06	11876.2	45428.9
January 10	61	27.63	6828.9	27604
January 11	53	27.35	6758.3	14970.7
January 12	27	2.56	633.2	966.9
January 13	27	2.68	661.7	459.3
January 14	16	2.7	667.4	983.7
January 15	13	3.69	912.3	902.9

In addition to identifying wildfires, FINN also provides emission rates for emitted gases and aerosols. The amount of emission rate for each species is a function of not only burnt area, but it also depends on the type of vegetation being burned. As a summary of the most significant estimations, Table 4 provides daily emission rates for the 3 main gaseous carbon contributors (CO₂, CO and CH₄), benzene as the most significant Volatile Organic Compounds (VOCs), and particulate matter with a diameter smaller than 2.5 µm (PM_{2.5}).

Table 4. Daily summary of carbon dioxide, carbon monoxide, methane, benzene, and PM_{2.5} emission rates from FINNv2.5

Date	CO ₂ [t]	CO [t]	CH ₄ [kg]	Benz. [kg]	PM _{2.5} [kg]
January 6	442.5	16.5	526.1	115.6	97.1
January 7	9665.3	476.1	16393.2	4916.4	4235.4
January 8	124668.5	6525.3	215956.5	70659.8	45419.9
January 9	76563.1	4258.6	144228.5	48424.9	30175.5
January 10	45606.6	2743.6	82110.5	27735.2	19008.2
January 11	25053.1	1094.8	42407.9	10092.3	14515.8
January 12	1630.1	61.4	2062	440.8	472.9
January 13	774.1	29.3	1013.1	213.5	256.1
January 14	1658.3	62	1972.7	433.3	364.0
January 15	1522.5	57.1	1852.1	402.7	373

FINN data also serve to extract a timeline for wildfire frequency and intensity along with more advanced statistics. To illustrate this timeline, Figure 3 combines the histograms showing the number of fires based on burnt area with the daily fire intensity PDF, which are plotted as continuous red lines. January 6 exhibits a small number of fires, but this figure quickly escalates over the next 3 days peaking at 184 wildfire loci on January 8. Then, the number of fires regresses to more seasonable values starting on January 10 with the last two days, January 14 and 15, registering a very small number of fires. The dynamics of fire intensity is slightly different as reflected in the shifting position of the PDFs. Wildfire intensity is very low on January 6. However, it peaks on January 7 when FINN identifies 2 loci belonging to the Eaton Fire with a FRW over 1,000 MW. The result is that the PDF has shifted significantly to the right and the bulk of energy release can be attributed to loci exceeding 100 MW. Over the following 4 days, the fires began to spread and multiply, but their intensities begin to decrease on average as fuel becomes scarcer causing the PDF to move to the left reflecting lower FRPs. The intensities in the last 4 days exhibit seasonal values similar to January 6.

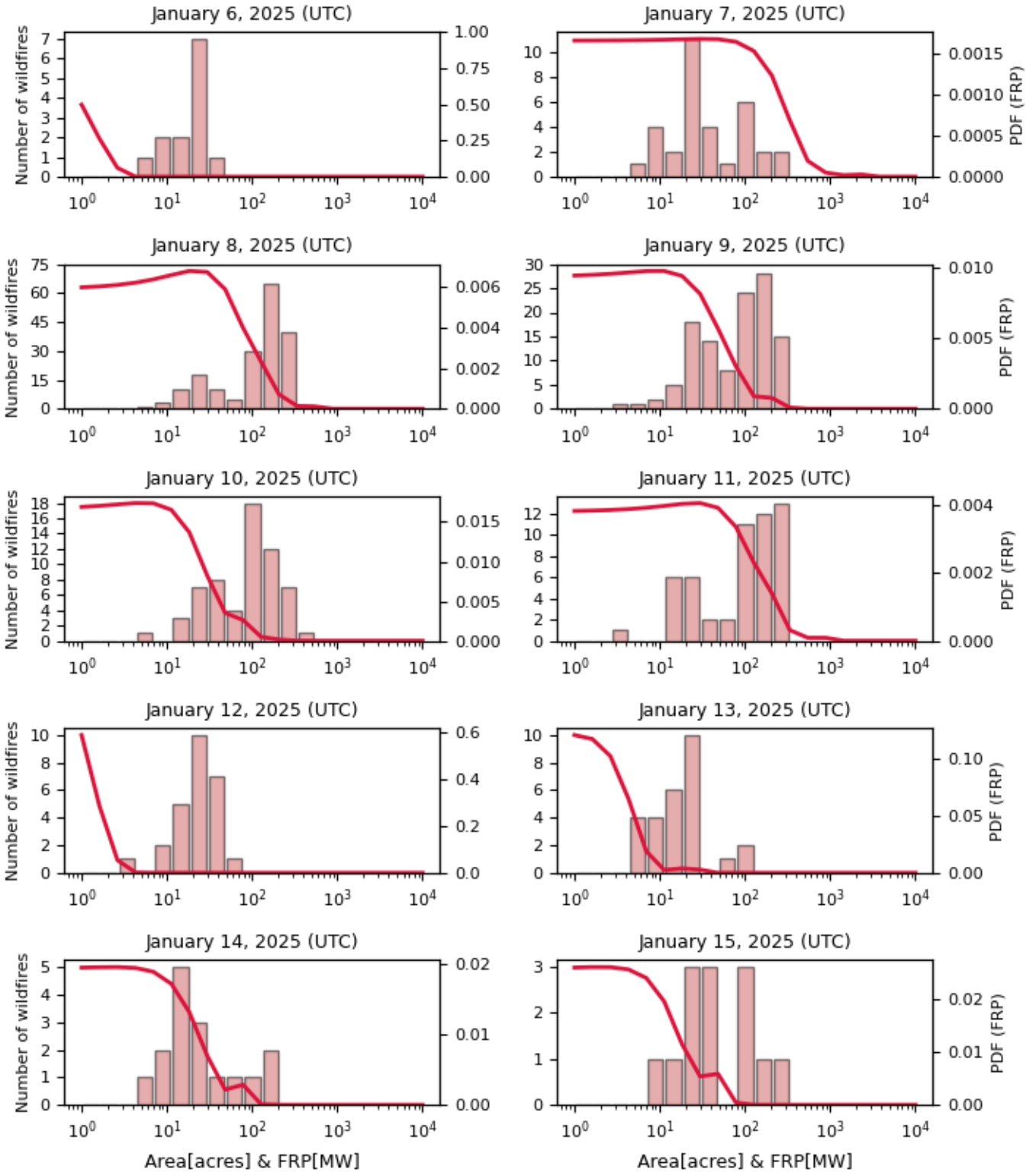


Figure 3. Histogram showing the number of wildfires as a function of their burned area and Probability Distribution Function of FRP [MW] from January 6 through January 15.

In addition to evaluating wildfire characteristics, FINN data are also needed to generate emission streams that can be read by CMAQ. This requires the completion of two tasks: (i) evaluation of plume heights; (ii) speciation of emitted species to the target

chemical mechanism. Based on the emission rates output by FINN, INCENDII maps them out to CMAQ species. The last step required to generate the emission streams is to evaluate plume properties. Firstly, the results from the ERA5 simulations are

used to interpolate the meteorological data for each wildfire based on latitude and longitude. Then, eqs. (1) and (6) are used to estimate hourly plume heights for the Sofiev's and hybrid scheme, respectively.

Figure 4 illustrates the daily distribution of plume heights. The hybrid scheme predicts higher plumes than the Sofiev's scheme, specifically for the high-intensity fires from January 7 through January 9.

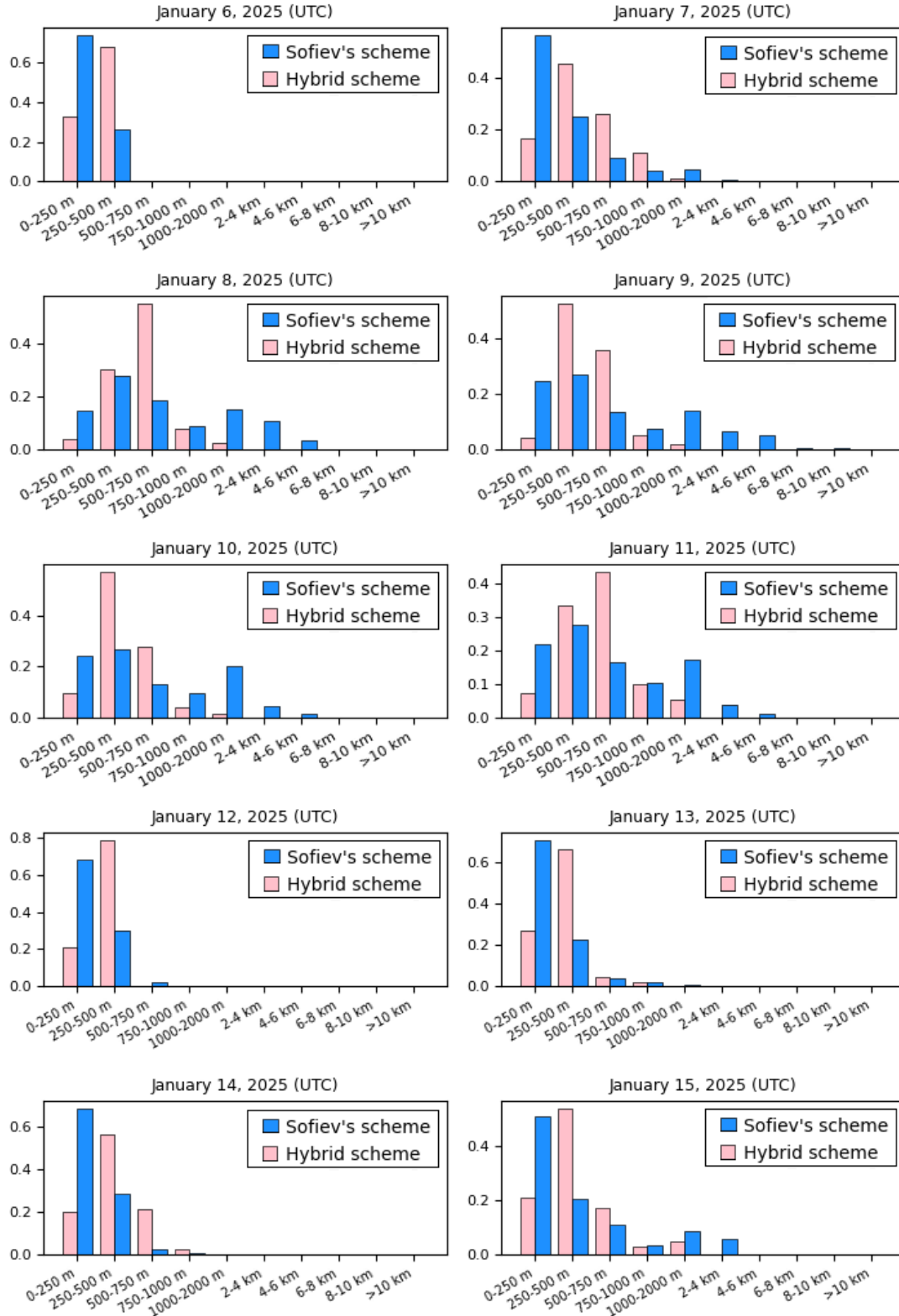


Figure 4. Distribution of plume heights from January 6 through January 15 using Sofiev's scheme versus the hybrid scheme.

CMAQ reads emission rates from emission streams with a specific format, and where each species detected by FINN must be properly speciated. A first group of species corresponds to some common gases such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and even GHG gases (e.g. CO₂), which do not require any extra speciation. The second group of species is composed by non-methane organic compounds (NMOC), which FINN speciates either to the MOZART- T1 [30], SAPRC99 [31] or GEOS-CHEM [32] chemical mechanism. Here, it is convenient to use the latter as most emission rates can be directly written to either a carbon-bond or CRACMM2 mechanism. In addition to gases, CMAQ requires speciation for aerosols and, more specifically, for particulate matter. FINN provides rates for total particulate matter (TPM), total particulate carbon (TPC), and PM_{2.5}. Total particulate carbon is divided into organic carbon (OC) and black carbon (BC), which can be mapped to particulate organic carbon (POC) and particulate elemental carbon (PEC). After subtracting the carbon component, PM_{2.5} requires sub-speciation for a better representation of aerosol composition. To accomplish this task, INCÆNDII follows EPA's SPECIATE profile 91102. Table 5 lists the resulting fractions.

Table 5. Speciation of PM_{2.5} after subtracting the carbon component following EPA's SPECIATE profile 91102.

Species	Symbol	Percentage
Particulate sulfate	PSO4	1.2605%
Particulate nitrate	PNO3	0.1323%
Particulate ammonium	PNH4	0.87915%
Particulate	PCL	4.14905%
Particulate aluminum	PAL	0.06075%
Particulate calcium	PCA	0.3858%
Particulate iron	PFE	0.0434%
Particulate magnesium	PMG	0.0314%
Particulate manganese	PMN	0.0016%
Particulate potassium	PK	2.93975%
Particulate	PSI	0.18185%
Particulate sodium	PNA	0.57335%
Particulate titanium	PTI	0.00515%

A difference between CRACMM2 and previous chemical mechanism such as carbon-bond is that particulate organic carbon and particulate non-methane organic compounds need to be sub-speciated depending on volatility. As the information about volatility products from wildfires is still scarce and, in some cases, contradictory, the most convenient protocol is to use the recommendations suggested by Pagonis et al. [34], which was based on a composite from different measurements.

5. Evaluation of emission rates

CMAQ accepts emissions as either gridded or point sources with the latter being internally transformed into gridded data. Table 6 lists the emitted species included in the air quality simulations, and if they originate from anthropogenic sources (ANTH), biogenic emissions (BIOG) or wildfires (FINN).

Table 6. List of species included in the emission streams and speciated to the CRACMM2 mechanism.

Species	CRACMM2	Phase	Source
Acetaldehyde	ACD	Gas	BIOG, FINN
Acetic acid	ORA2	Gas	BIOG, FINN
Acetone	ACT	Gas	BIOG, FINN
Acetylene	ACE	Gas	ANTH, FINN
Alkanes	HC3/5/10	Gas	ANTH
Alkene	OLT	Gas	FINN
Alpha-pinene	API	Gas	BIOG
Ammonia	NH3	Gas	ANTH, FINN
Benzene	BEN	Gas	ANTH, FINN
Carbon monoxide	CO	Gas	ANTH, BIOG, FINN
Carbon dioxide	CO2	Gas	FINN
Ethane	ETH	Gas	ANTH, BIOG, FINN
Ethanol	EOH	Gas	BIOG
Ethene	ETE	Gas	ANTH, BIOG, FINN
Formaldehyde	HCHO	Gas	ANTH, BIOG, FINN
Formic acid	ORA1	Gas	BIOG
Glyoxal	GLY	Gas	FINN
Higher aldehydes	ALD	Gas	ANTH, BIOG
Isoprene	ISO	Gas	ANTH, BIOG
Ketones	KET	Gas	ANTH, BIOG, FINN
Methane	ECH4	Gas	ANTH, BIOG, FINN
Methanol	MOH	Gas	BIOG
Methyl glyoxal	MGLY	Gas	FINN
Monoterpenes	TRPN	Gas	ANTH, BIOG
Nitric oxide	NO	Gas	FINN
Nitrogen dioxide	NO2	Gas	ANTH, FINN
Sesquiterpenes	SESQ	Gas	BIOG
Sulfur dioxide	SO2	Gas	ANTH, FINN
Toluene	TOL	Gas	ANTH, BIOG, FINN
Xylene	XYL	Gas	ANTH,
Aluminum	PAL	Aerosol	ANTH, FINN
Ammonium	PNH4	Aerosol	ANTH,
Calcium	PCA	Aerosol	ANTH, FINN
Chloride	PCL	Aerosol	ANTH, FINN
Iron	PFE	Aerosol	ANTH, FINN
Magnesium	PMG	Aerosol	ANTH, FINN
Manganese	PMN	Aerosol	ANTH, FINN
Nitrate	PNO3	Aerosol	ANTH, FINN
Other particulates matter	PMOTHR	Aerosol	ANTH, FINN
Particulate elemental carbon	PEC	Aerosol	ANTH, FINN
Particulate non-carbon organic matter	PNCOM (Volatility)	Aerosol	ANTH, FINN
Particulate organic carbon	POC (Volatility)	Aerosol	ANTH, FINN

Potassium	PK	Aerosol	ANTH, FINN
Silicon	PSI	Aerosol	ANTH, FINN
Sodium	PNA	Aerosol	ANTH, FINN
Sulfate	PSO4	Aerosol	ANTH, FINN
Titanium	PTI	Aerosol	ANTH, FINN

In addition to wildfire emission streams, CMAQ also needs emission streams detailing anthropogenic and biogenic sources interpolated from COPERNICUS.

6. Air quality assessment

In general, the amount of observational data quantifying concentrations of airborne pollutants is significantly smaller than for meteorological data. This is especially challenging in regards to hourly measurements as a large percentage of available datasets provide average daily measurements rather than hourly ones. Here, and in order to evaluate the numerical predictions, data from WAQI (World Air Quality Index) have been used. WAQI [33] provides millions of measurements across hundreds of stations worldwide in all continents, and is a very useful tool for researchers across the world. However, and because of the amount of information, hourly readings are scarce and not available for the specific combination of region and time period of interest. Instead, the available information include readings of maximum, minimum, median, and the first and third quartiles (Q1 & Q3). Table 7 lists the latitudes and longitudes for WAQI locations used here. The stations listed in Table 7 are located in the Los Angeles county and exhibit significant increases in AQIs (Air Quality Index) versus seasonal values in the days following the onset of the wildfires.

Table 7. Latitude and longitude for WAQI stations.

	Station	Latitude	Longitude
WAQI-1	Toluca Lake ES	34.1595°N	118.3613°W
WAQI-2	Eagle Rock ES	34.1359°N	118.2130°W
WAQI-3	Sierra Park ES	34.0817°N	118.1692°W
WAQI-4	Berendo MS	34.0493°N	118.2943°W
WAQI-5	Utah ES	34.05°N	118.24°W
WAQI-6	Garfield HS	34.0255°N	118.1578°W
WAQI-7	Walgrove ES	34.0059°N	118.4517°W
WAQI-8	Westport Hts ES	33.9670°N	118.3884°W
WAQI-9	Dolores ES	33.84°N	118.27°W
WAQI-10	Wilmington Pk ES	33.78628°N	118.2457°W

The air quality simulations use CMAQ v5.7 with CRACMM2 as the chemical mechanism and STAGE as the deposition module, which represent the latest development of this HPC software. The CMAQ simulations use the favored trimming of 5 cells in each boundary resulting in an updated domain covering 35,000 km². Before performing the

simulations, it is necessary to complete two steps: (i) process the WRF-ERA5 output file with MCIP (Meteorology-Chemistry Interface Processor) in order to generate the necessary files holding variables such as velocities, temperatures or water vapor concentration, which are required by CMAQ to compute transport phenomena; (ii) generate the files holding the initial and boundary conditions. To improve the accuracy of these conditions, this task uses the ‘regrid’ approach instead of using the more conventional predetermined concentration profiles. This regridding step requires the results from a coarser simulation so that they can be interpolated; here, this simulation is EPA’s north hemispherical simulation with a 108 km resolution for 2019. The file holding the January data must be time-shifted and converted to the CRACMM2 mechanism before BCON and ICON can be used to generate the boundary and initial boundary files. Once all these tasks are complete, and in order to illustrate the impact of wildfires, the computations include a first simulation without wildfire emissions followed by simulations using the hybrid and Sofiev’s schemes. CMAQ generates several output files, from which the Averaged Explicit Lumped Model Output (AELMO) file has been used for most postprocessing tasks. The dynamics of airborne pollutants is better illustrated with the aid of temporal animations or snapshots in its place. Figure 5a & 5b show snapshots of PM_{2.5} concentration (Sofiev’s scheme) across the domain every 12 hours from January 7 (5 pm PST) -shortly after the Eaton Fire broke out- through January 11 (5 pm PST), and at 5 am on January 13, 14 and 15. For reference, Figure 5a & 5b also shows the WAQI locations. As the Eaton Fire ignites around 4 pm local time in the afternoon of January 7, the simulations capture the increase in PM_{2.5}. Simultaneously, the strong Santa Ana winds drag pollutants from the Eaton Fire in the southwest direction causing PM_{2.5} concentrations to begin rising in some of the most densely populated Los Angeles neighborhoods. As the Eaton Fire keeps burning for another 3 days, the dynamics of PM_{2.5} is driven by the competition between emissions and the dispersion by the winds. Once the fire begin to subside during January 11, the winds continue pushing airborne pollutants towards the ocean. A slightly different dynamics happens in the areas near the shoreline including the Pacific Palisades neighborhood, which is the area most affected by material damage: Initially and during the first 24 hours, the wind blowing in the southwest

direction push most pollutants away and only a relatively small area notices any increase in $PM_{2.5}$ concentration; however, and when the winds near the shoreline shift direction on January 9, the area affected by the emissions from the Palisades Fire becomes larger including populated area where these emissions can add up to the ones having been

dragged from the Eaton Fire. In addition to these 2 major fires, the minor fires also contribute to the increase in $PM_{2.5}$. Even after the Eaton and Palisades Fires are contained, several other minor fires ignited in the northern section of the Angeles National Forest, and the one at Ventura county costing another life as shown in the last 3 snapshots of Figure 5b.

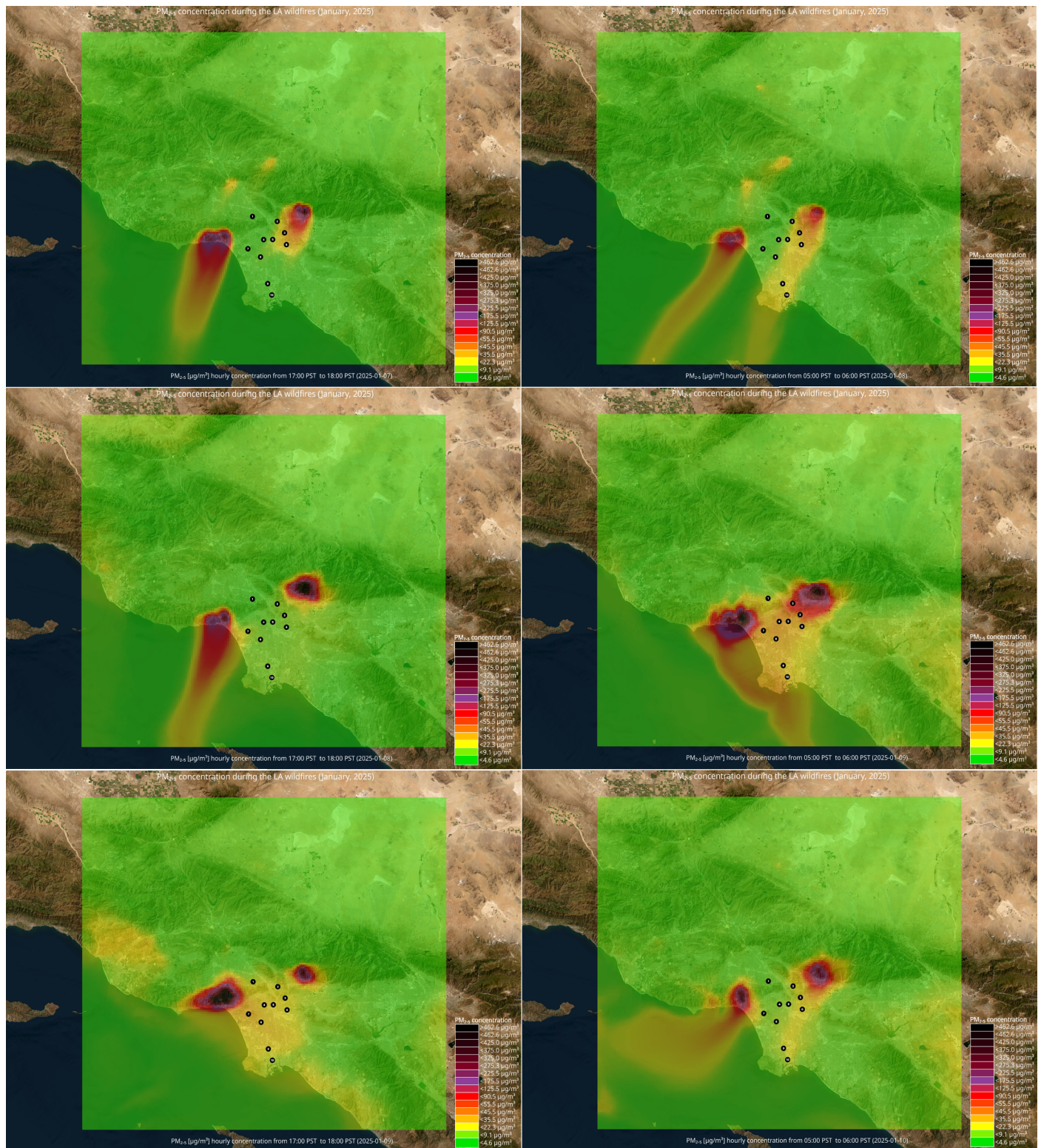


Figure 5a. $PM_{2.5}$ concentrations from January 7 (5 pm PST) when the major fires had just broken out through January 10 (5 am PST) every 12 hours. The figure also shows the locations of the WAQI stations.

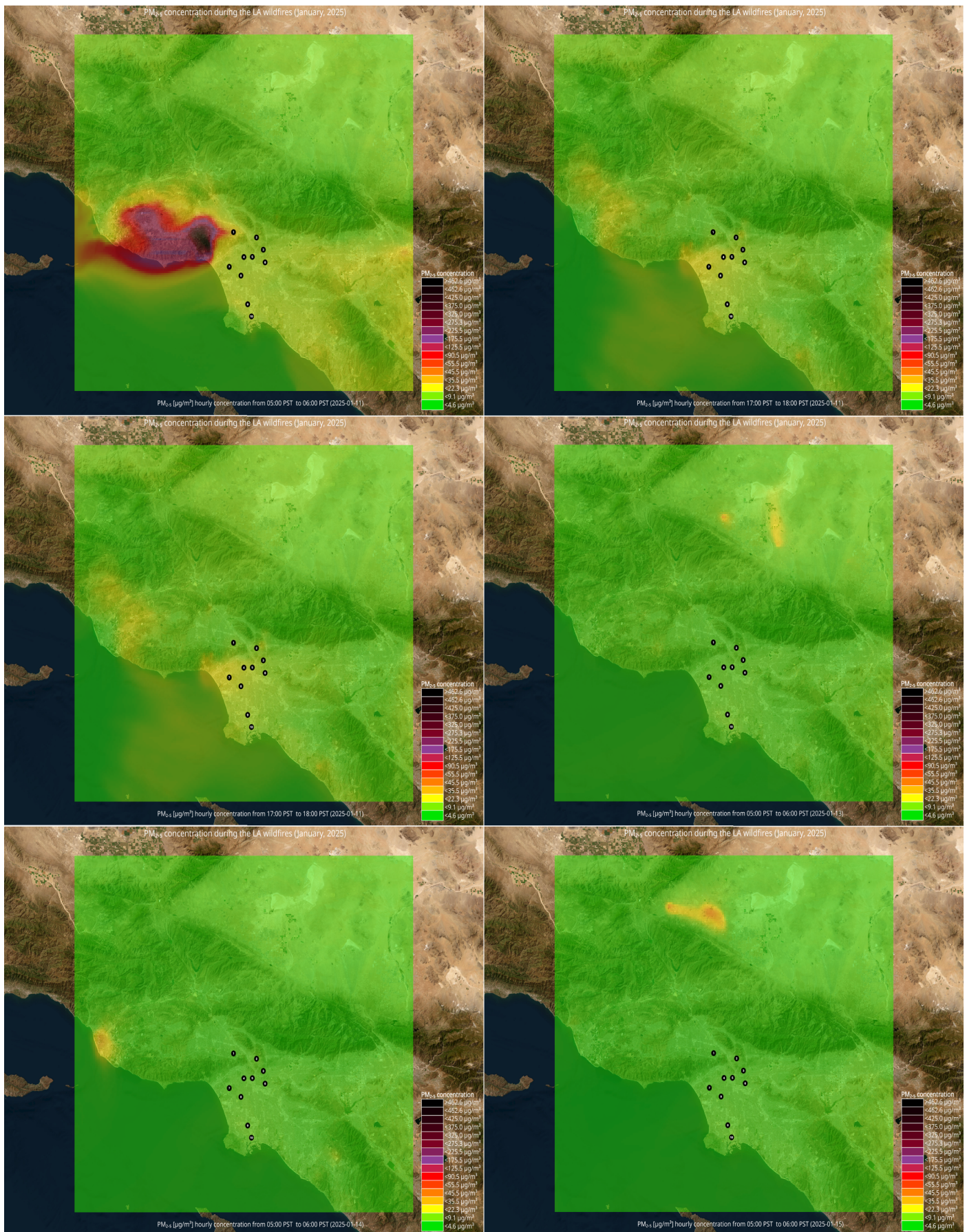


Figure 5b. PM_{2.5} concentrations from January 10 (5 pm PST) to January 11 (5 pm PST) every 12 hours, and on January 13, 14, and 15 at 5 am..

The dynamics just described also reflects on any interpolated pollutant concentration. Figure 6 shows the hourly averages for AQI for $PM_{2.5}$ from the

CMAQ simulations along with the daily maximum, minimum, media, Q1 and Q3 measurements from the 10 WAQI stations.

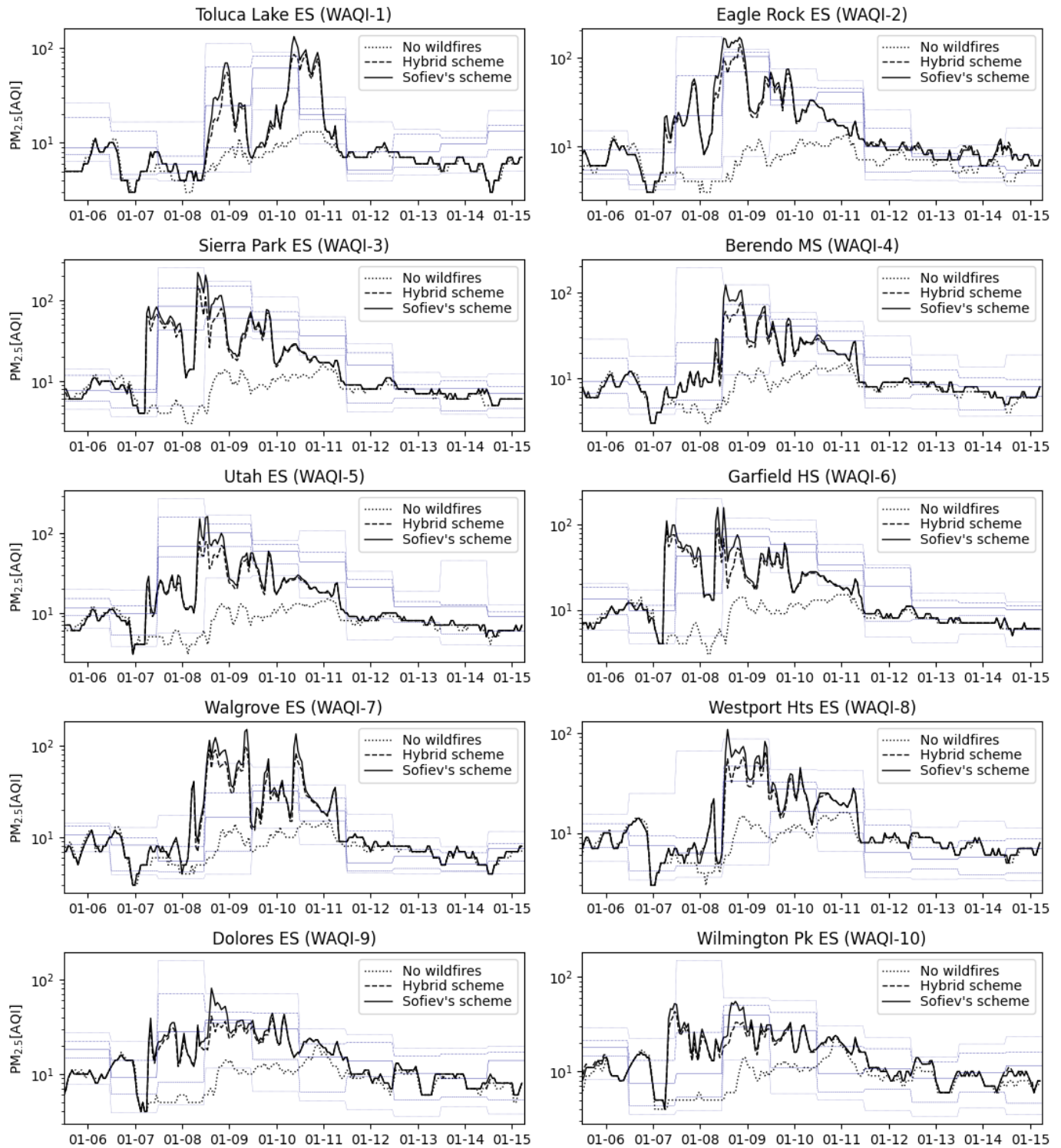


Figure 6. Hourly predictions for $PM_{2.5}$ [AQI] at the emission stations from January 6 through January 15.

The first station is located west of the Angeles National Forest and its AQI for PM_{2.5} did not exhibit any significant increase until January 9; however, this increase is lower than for the other stations, which reflects in both measurement and numerical results. The next five stations are south or slightly southwest of the Eaton Fire and register AQIs higher than 100 on January 8 as the winds push the pollutants towards this area. More specifically, the stations at Sierra Park Elementary School (WAQI-3) and Utah Elementary School (WAQI-5) exhibit AQIs greater than 200, which are considered very unhealthy levels. The next four stations are closer to the shoreline and registered lower AQIs but still in the unhealthy range. The first two are affected by the emissions from the Eaton Fire being brought by the winds and the emissions from the Palisades Fire once

the winds begin to shift near the coast on January 9. The last 2 stations are mostly affected by the Eaton Fire with little emissions coming from the Palisades Fire and their AQI peaks are lower than for other stations. These peaks also lag a few hours versus stations WAQI-2 to WAQI-6 due to the time that it takes the pollutants to cover the distance between the stations.

In addition to PM_{2.5} concentration, it is also feasible to show smoke concentrations [mg/m²] representing column values. These values come from aggregating PM_{2.5} concentration from the terrain surface to the top of the domain usually in the stratosphere. For example, Figure 7 shows the smoke predictions at the break of January 9 when the smoke created by the wildfires affected the Los Angeles downtown and its closest neighborhoods.

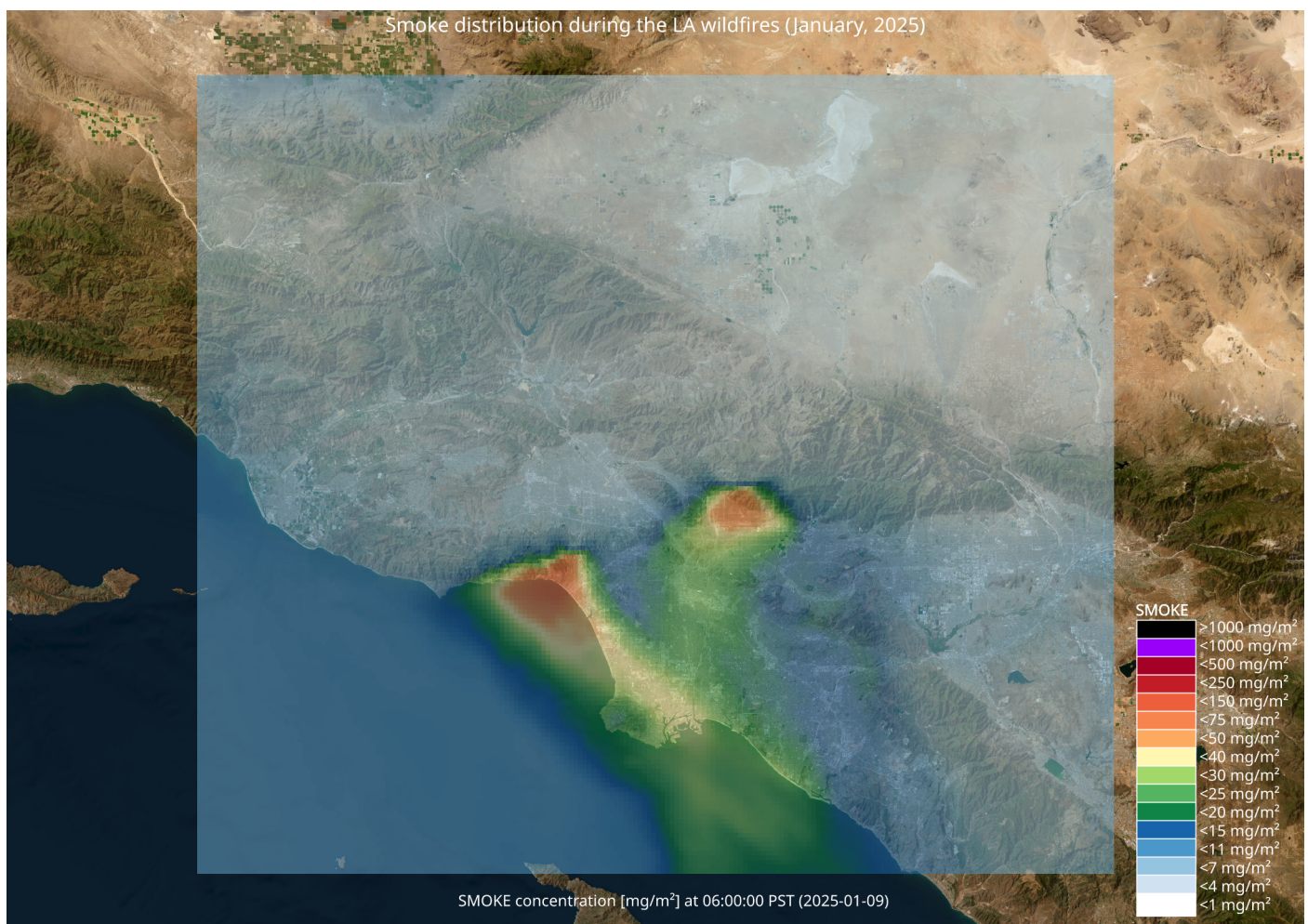


Figure 7. Smoke distribution measured in mg/m² as a result of the wildfire emissions on January 9 at 6 am (PST).

Another variable of interest is any rise in the concentration of VOCs, especially benzene that is highly toxic and carcinogenic. Figure 8 shows the hourly concentrations for benzene at the WAQI stations from the CMAQ simulation including wildfires (Sofiev's scheme) from January 6 through January 12.

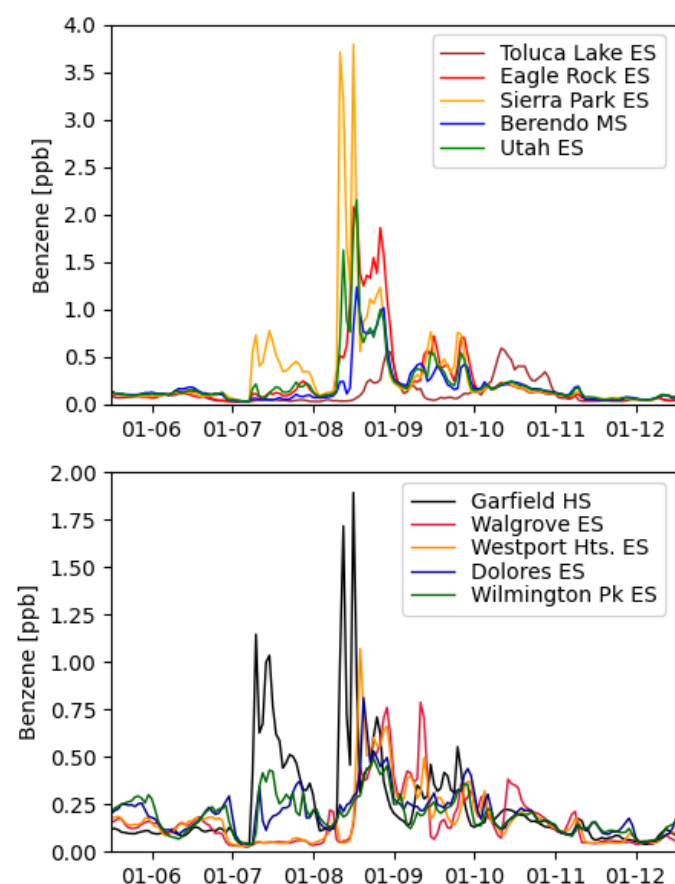


Figure 8. Predicted temporal concentration for benzene from January 6 through January 12.

The predictions show very low concentrations the first two days. However, the onset of the wildfires causes a sharp increase in these concentrations that peak between January 8 and January 10. After January 11, the concentrations return to more normal magnitudes. The estimated concentrations are concerning -particularly during the peak days- as several locations exhibit values exceeding some of the exposure limits proposed by OSHA (Occupational Safety and Health Administration), NIOSH (National Institute for Occupational Safety and Health), ACGIH (American Conference of Government Industrial Hygienists), and California OEHHA. Even though the recommended limits from these organizations are for work places, it is significant to assess whether they were surpassed in an urban environment especially considering that benzene concentrations diminish more slowly in

indoor conditions than outdoors [3]. The first recommended exposure level is for an 8-hour period ranging from 0.1 ppm (NIOSH) to 1 ppm (OSHA & OEHHA). The numerical results suggest that the northern neighborhoods near the Angeles National Forest might have surpassed even the OSHA and OEHHA threshold during the night of January 9. The limits for short-term exposure (15-minute) are higher with OSHA, NIOSH, and ACGIH recommending 5 ppm, 1 ppm, and 2.5 ppm, respectively. OEHHA's recommendations include an exposure limit of 8 ppb for a full hour. The prediction at Sierra Park suggests that this area might have been exposed to benzene concentrations nearing 4 ppb, which could be considered as especially dangerous.

A direct comparison between numerical results versus measurements is not feasible, but some insight can be gained with an indirect evaluation. The results reported by Yao et al. [3] involve indoor and outdoor measurements, and are divided in 3 phases. Here, the phase of interest in phase 1 that covers January 8 through January 15, where Yao et al. [3] reported a median outdoor concentrations of 0.38 ppb and a Q1 of 0.27 ppb. By comparison, Table 8 summarizes the median benzene concentration along with their Q1 and Q3 at the WAQI stations for 8 days between January 8 and January 15, and for 3 days between January 8 and January 10. Even though the computed medians for January 8-15 are lower, the estimates for several stations are close to the value reported by Yao et al. [3]. Furthermore, restricting the analysis to the 3 most unfavorable days shows values even higher. Both in-situ measurements and numerical predictions suggest that more observational and numerical assessment is needed to establish a relationship between wildfire emissions and dangerous benzene concentrations, specifically in urban areas where the consequences of long-lasting indoor exposition might be greater.

Table 8. Numerical predictions for median and average benzene concentration at the WAQI stations.

	Median 1/8-1/15	Q1/Q3 (ppb) 1/8-1/15	Median 1/8-1/10	Q1/Q3 (ppb) 1/8-1/10
WAQI-1	0.051 ppb	0.041/0.091	0.062 ppb	0.041/0.159
WAQI-2	0.075 ppb	0.053/0.190	0.242 ppb	0.122/0.564
WAQI-3	0.093 ppb	0.061/0.298	0.397 ppb	0.201/0.652
WAQI-4	0.081 ppb	0.062/0.183	0.191 ppb	0.079/0.384
WAQI-5	0.092 ppb	0.068/0.195	0.217 ppb	0.156/0.465
WAQI-6	0.109 ppb	0.068/0.266	0.336 ppb	0.187/0.502
WAQI-7	0.072 ppb	0.051/0.186	0.164 ppb	0.052/0.362
WAQI-8	0.094 ppb	0.056/0.168	0.174 ppb	0.056/0.339
WAQI-9	0.162 ppb	0.119/0.226	0.249 ppb	0.209/0.321
WAQI-10	0.168 ppb	0.112/0.216	0.234 ppb	0.191/0.311

7. Conclusions

The January 2025 Southern California wildfires had catastrophic consequences and, one year after their impact, several scientific and economic studies are beginning to shed light in different aspects of this tragedy. It is anticipated that other reports focused on the different aspects and consequences of these fires will likely be released during 2026.

The main objective of this work was to numerically recreate the meteorological conditions responsible for the quick spread of the January 2025 Southern California wildfires while using this background to evaluate wildfire characteristics and air quality. In order to achieve these goals, WRF with a computational domain covering the Los Angeles metropolitan area and a 1-km resolution was used. The WRF simulations considered an urban environment and used 4 different datasets GFS, NAM, MERRA2, ERA5 with the latter resulting in the most accurate predictions. The identification of wildfires and their intensity combined the FINNv2.5 inventory with the WRF output. In order to evaluate emissions resulting from wildfires, and based on their characteristics and atmospheric conditions at any particular location, it is feasible to use different models calculating maximum plume height. The present study has mostly used Sofiev's scheme, but also introduced a novel scheme based on cap theory. The objective of the latter is to remedy plume height under-prediction for wildfires reaching the free troposphere.

The air quality simulations used CMAQ v5.7 with CRACMM2 as the chemical mechanism. The ERA5 WRF output provided the field background dictating transport phenomena. The CMAQ results serve to evaluate the spatial-temporal concentration across the Los Angeles area of several species including PM_{2.5} and benzene. The numerical results show that the intensity and timing of peak PM_{2.5} concentration depend on the relative location to the fires, which agree qualitatively with observational measurements. Furthermore, the numerical results confirmed that the Eaton Fire was mainly responsible for air quality deterioration even though the Palisades Fire burned almost twice the amount of vegetation. The latter fire had limited impact mostly concentrated in the southwest Los Angeles area. The simulations also captured significant increases in volatile organic compounds (VOCs) with benzene values being of particular concern because of their potential harmful effects.

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Annex 1 – List of software and models mentioned in the report.

CHIMERE - Chemical Transport Model software
Open source; main developer: Polytechnique (France)

Community Multiscale Air Quality (CMAQ) Model - Chemical Transport Model software
Open source; main developer: U.S. Environmental Protection Agency (EPA)

Energy Exascale Earth System Model - Chemical Transport Model software
Open source; main developer: U.S. Department of Energy (DOE)

ECMWF Reanalysis v5 (ERA5) - Reanalysis dataset
Main developer: ECMWF

Geophysical Fluid Dynamics Laboratory's Atmospheric Model - Chemical Transport Model software
Main developer: U.S. NOAA

Global Forecast System (GFS) - Forecasting Model
Main developer: U.S. National Oceanic and Atmospheric Administration (NOAA)

INCÆNDII – Wildfire Multiphase software
Proprietary software (Odycloud)

Modern-Era Restrospective analysis for Research and Applications, version-2 (MERRA-2) -
Reanalysis dataset
Main developer: U.S. NASA

Model for Prediction Across Scales (MPAS) – Atmosphere - Atmospheric Model software
Open source; main developer: U.S. National Center for Atmospheric Research (NCAR)

North American Mesoscale (NAM) Forecast System - Forecasting Model
Main developer: U.S. National Oceanic and Atmospheric Administration (NOAA)

Rapid Refresh Forecast System (RRFS) - Forecasting Model
Main developer: U.S. National Oceanic and Atmospheric Administration (NOAA)

Weather Research & Forecasting (WRF) Model - Atmospheric Model software
Open source; main developer: U.S. National Center for Atmospheric Research (NCAR)