Assessing Wildfire PM2.5 Forecasting Accuracy and its Impacts on Decision-Making: A Model Comparison for Los Angeles 2025

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I. Introduction

i. Background

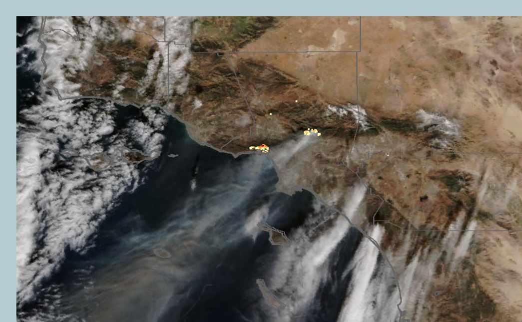


Fig 1. True color of Southern California on 01/10/2025 during the wildfires

- From January 7-31, 2025, a series of wildfires affected the Los Angeles metropolitan area and San Diego County in California. The fires were exacerbated by drought conditions, low humidity, vegetation build up, and the Santa Ana winds.
- Wildfires are a major source of PM2.5, an air pollutant that adversely affects human health and increases chances of respiratory diseases.
- However, predicting PM2.5 concentrations due to wildfire activity is difficult due to uncertainties in fire emissions, fire plume rise, and other model inputs/processes.

ii. Objective

- Evaluate the accuracy of different forecasting models against ground-level observations
- Examines how different model results can inform policy and decision-making at both local and federal levels

II. Methodology

i. Study Site

- Latitude: [32.2440, 34.9162]
- Longitude: [-120.2208, -115.8922]

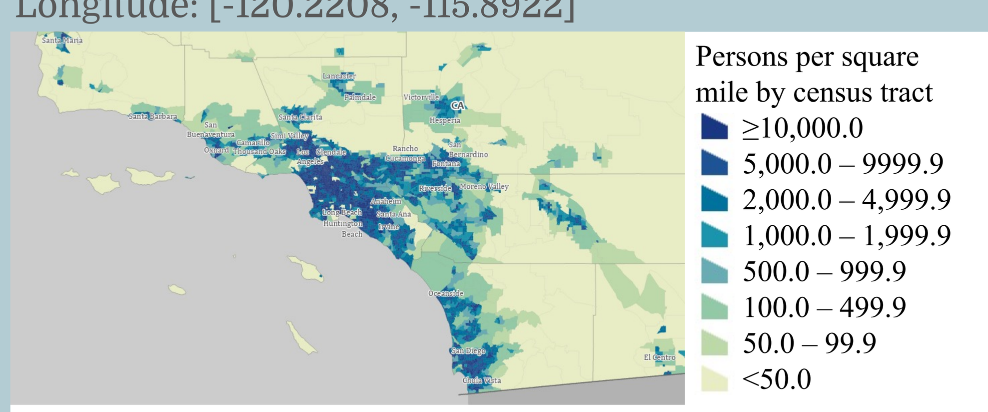


Fig 2. Population density of Southern California (2020 US Census)

- EPA AirNow hourly ground-level PM2.5 → 41 stations
- US Census 2020 → 5076 GEOIDs

ii. Model Forecasting

- High-Resolution Rapid Refresh-Smoke (HRRR-Smoke)
- Environment and Climate Change Canada (ECCC)
- National Air Quality Forecasting Capability (NAQFC)
- Navy Aerosol Analysis and Prediction System (NAAPS)
- Goddard Earth Observing System-Composition Forecasting (GEOS-CF)
- Global Ensemble Forecast System-Aerosols (GEFS -Aerosols)

- Multi-Model Ensemble Mean (E_mean) → EQ: $\bar{M} = \frac{1}{N}\sum_{j=1}^{N} M_j$
- Multi-Model Ensemble Median (E_median)

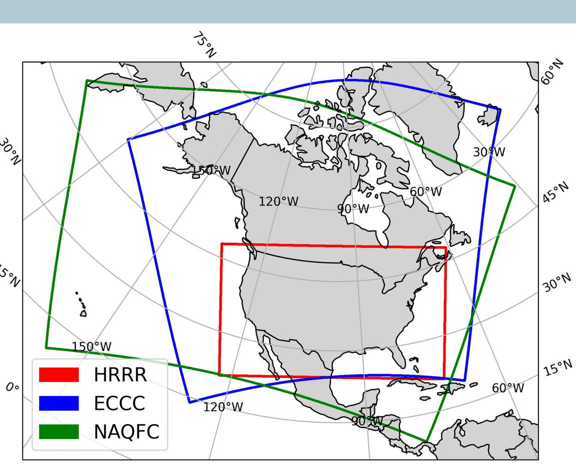


Fig 3. Domain of regional models HRRR, ECCC, and NAQFC. NAAPS, GEOS-CF, and GEFS are global models.

iii. Calculations

- Hit Ratio (HR) = obs>35 / (model>35 + obs>35)
- False Alarm Ratio (FAR) = model>35 / (model>35 + obs<35)

III. PM2.5 Model Predictions

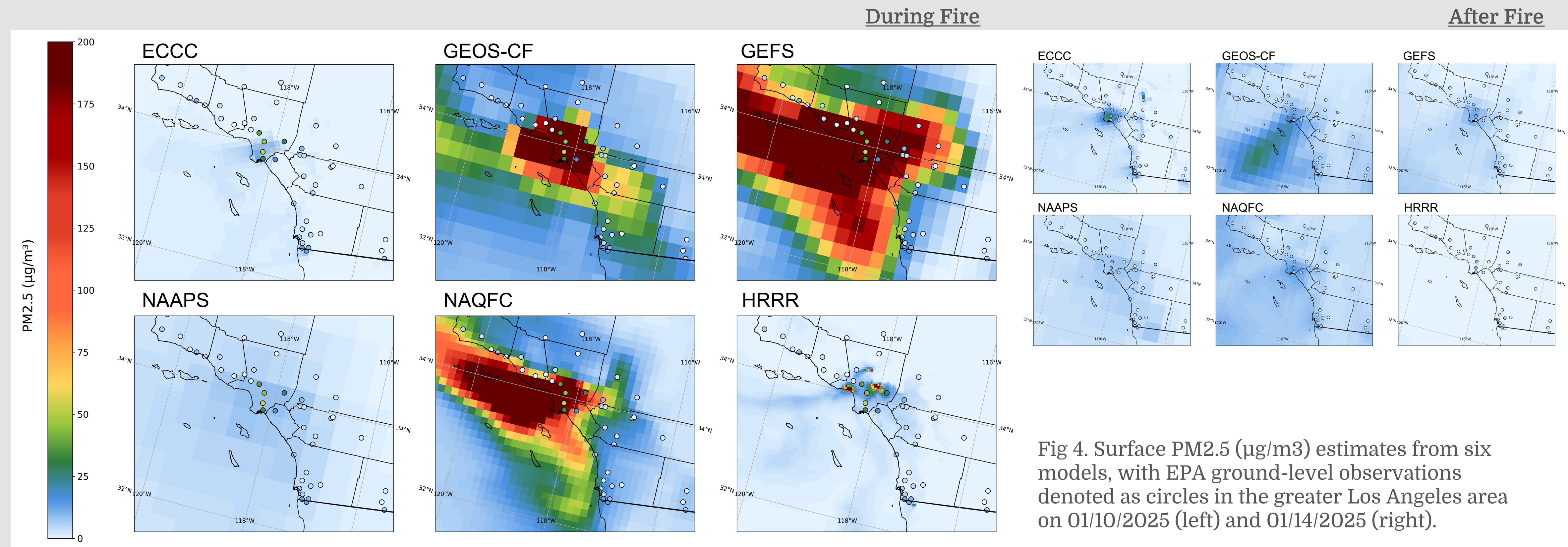
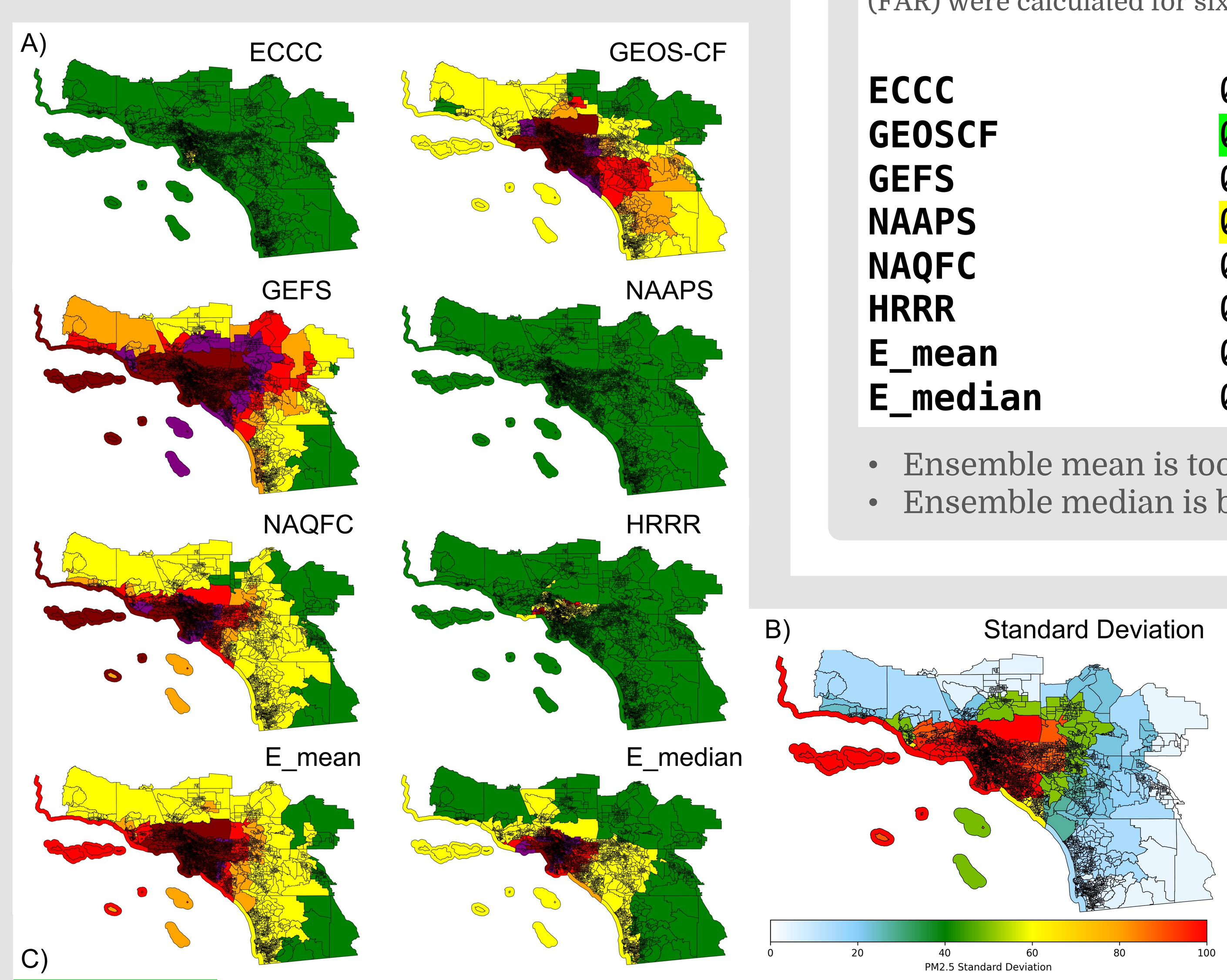


Fig 4. Surface PM2.5 (μg/m3) estimates from six models, with EPA ground-level observations denoted as circles in the greater Los Angeles area on 01/10/2025 (left) and 01/14/2025 (right).

- High uncertainty when predicting PM2.5 during a fire compared to when there is no fire

IV. Air Quality Index (AQI): Population Exposure



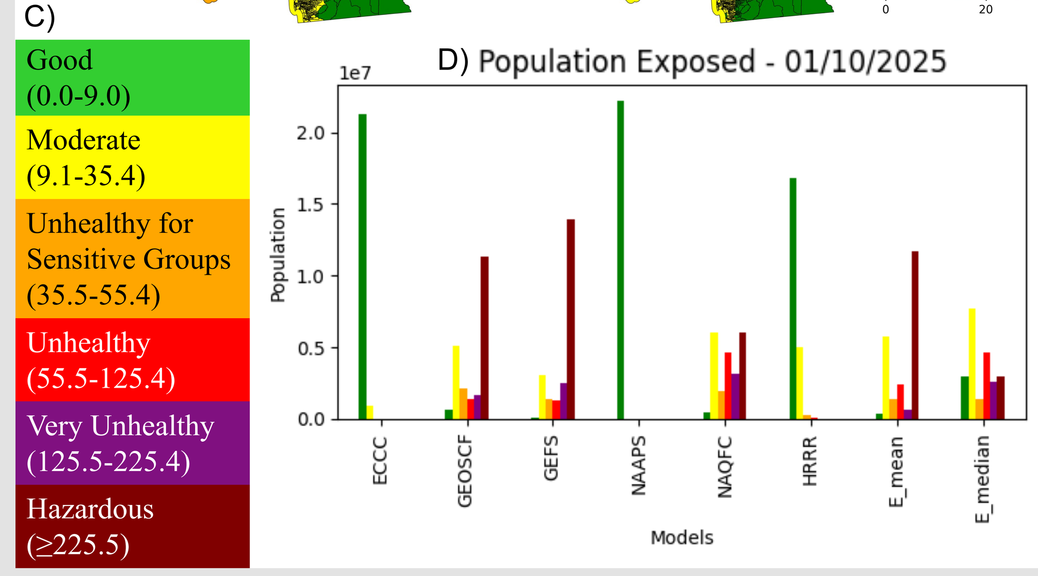


Fig 5. 2023 EPA AQI standards for PM2.5 in μg/m³ (C); Population affected by varying levels of PM2.5 (D) and the distribution of those levels (A) in the greater Los Angelos area; Standard deviation of PM2.5 levels (B)

- High variability in PM2.5 concentrations between models suggests a decrease in prediction accuracy as PM2.5 concentrations increase
- Sensitive groups require accurate warnings 1-2 days in advance to prepare

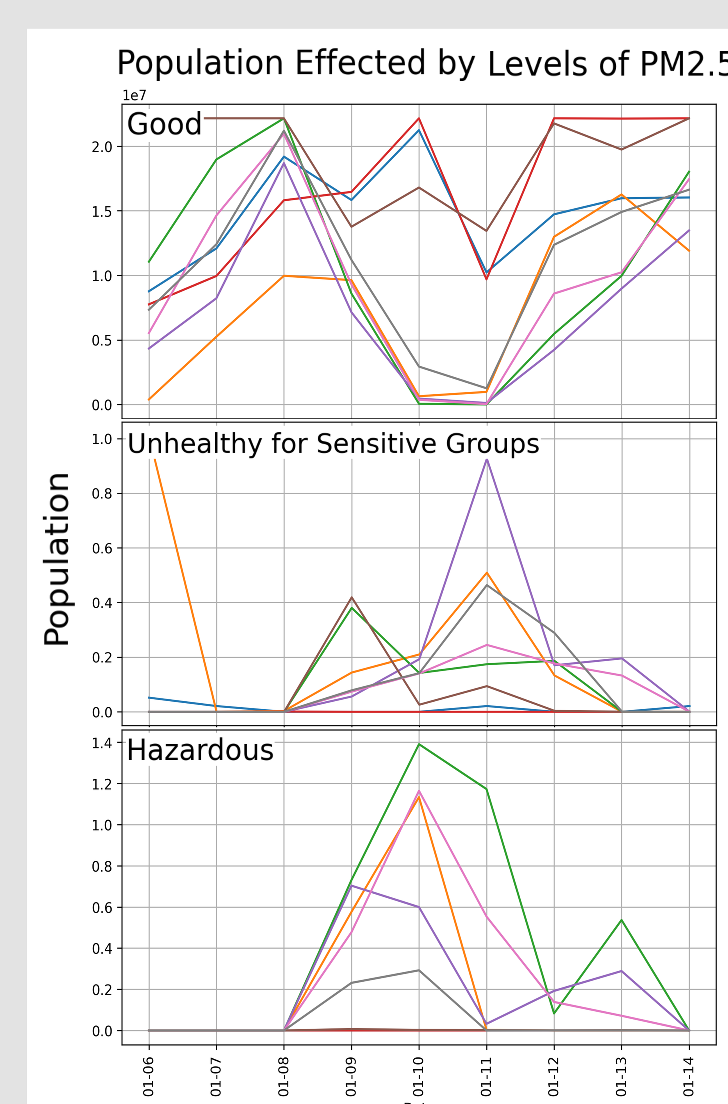


Fig 6. Population affected by 'Good' (top), 'Unhealthy for Sensitive Groups' (middle), and 'Hazardous' (bottom) levels of PM2.5 based on six models and their ensemble mean and median over time.

V. Statistics

- Green → Best
- Yellow → Worst

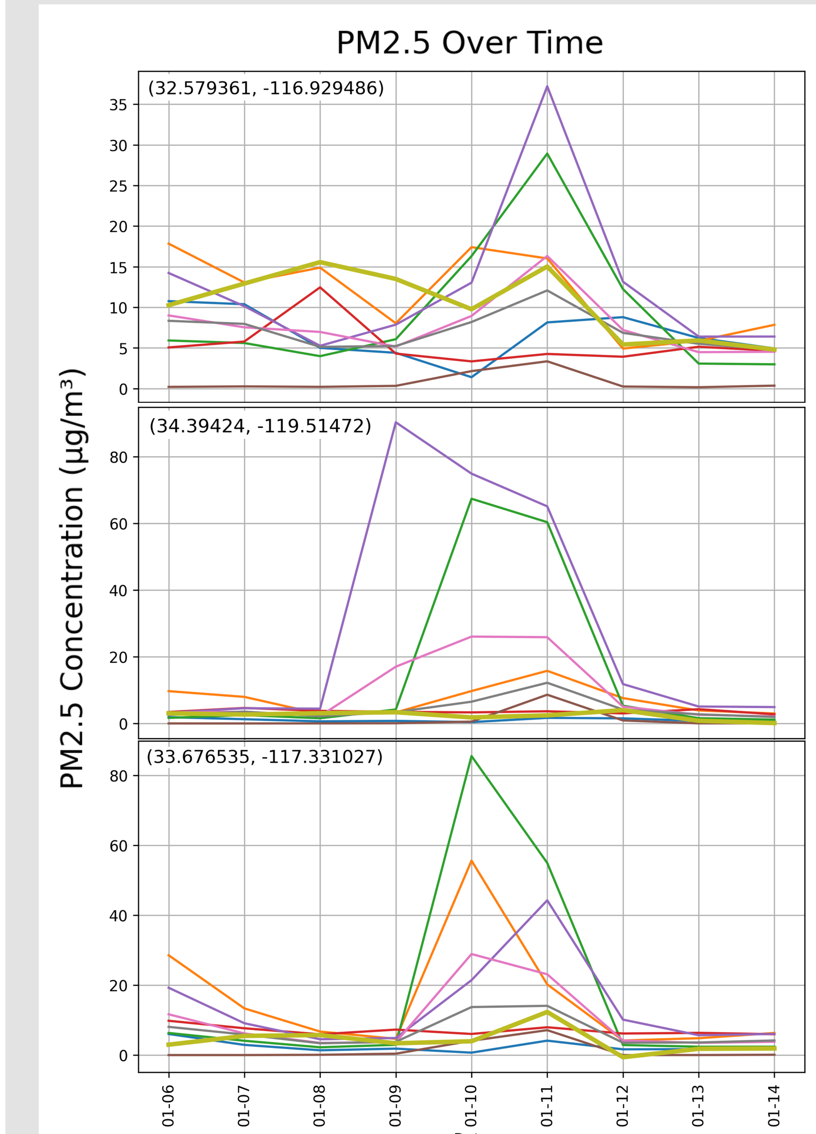
Table 1. Pearson correlation (Corr), mean bias error (MBE), hit ratio (HR), and false alarm ratio (FAR) were calculated for six models and their ensemble mean and median.

	Corr	MBE	HR	FAR
ECCC	0.714266	-7.00165	1.0	0.0
GEOSCF	0.858345	114.117776	0.15	0.320755
GEFS	0.781831	627.302723	0.103448	0.419355
NAAPS	0.611647	-3.851108	1.0	0.0
NAQFC	0.684871	75.798198	0.166667	0.294118
HRRR	0.642292	-5.462172	1.0	0.0
E_mean	0.822405	133.483961	0.176471	0.28
E_median	0.844214	22.643816	0.3	0.162791

- Ensemble mean is too influenced by overestimation (high MBE) of other models
- Ensemble median is better than mean in all categories

VI. PM2.5 Over Time

- Accuracy of PM 2.5 prediction for each model varies at different locations



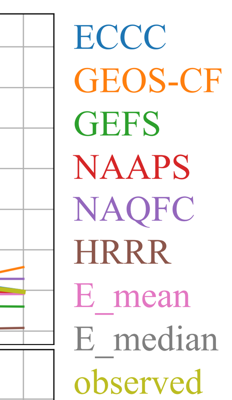


Fig 7. Average PM2.5 concentrations over nine days (01/06-01/14) based on six models and their ensemble mean and median at 32.579361, -116.929486 (top), 34.39424, -119.51472 (middle), and 33.676535, -117.331027 (bottom)

- Best model per location
  - 32.579361, -116.929486 → GEOS-CF
  - 34.39424, -119.51472 → ECCC, NAAPS
  - 33.676535, -117.331027 → ECCC, NAAPS, HRRR
- GEFS and NAQFC overestimate PM2.5 at all locations

VII. Conclusion

i. Key Findings

- Unweighted ensemble mean is too influenced by other models' overestimations.
- Models GEFS, GEOS-CF, and the ensemble mean largely overestimate PM2.5 concentrations.

ii. Decision and Policy Makers

- Public Health Alerts and Warnings
- Regulatory and Emission Control Measures
- Emergency Response and Mitigation Strategies
- Long-term Urban and Environmental Planning
- Climate and Energy Policy Adjustments

- **Underestimation:** health impacts, weaken emission regulations
- **Overestimation:** unnecessary restrictions, overreactions, wasted resources

Acknowledgements

This study is financially supported by the NASA Earth Action: Wildland Fires. We thank NASA, NOAA, ECCC, and EPA for providing PM2.5 emission data.

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