From COVID-19 to Future Electrification: Assessing Traffic Impacts on Air Quality by A Machine-learning Model

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RESEARCH ARTICLE

From COVID-19 to future electrification: Assessing traffic impacts on air quality by a machine-learning model

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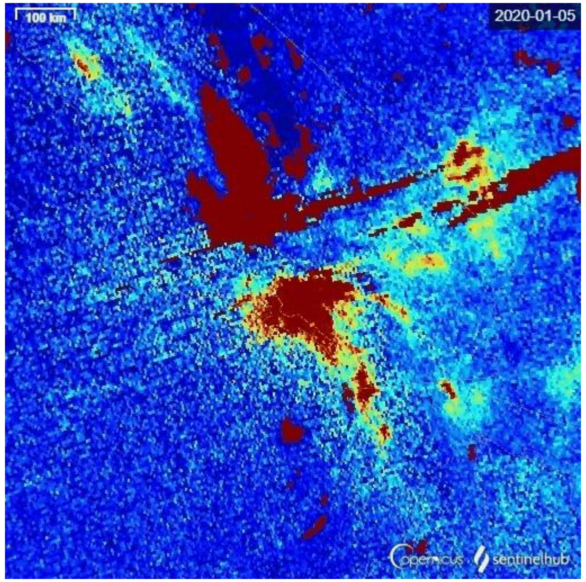
Abstract

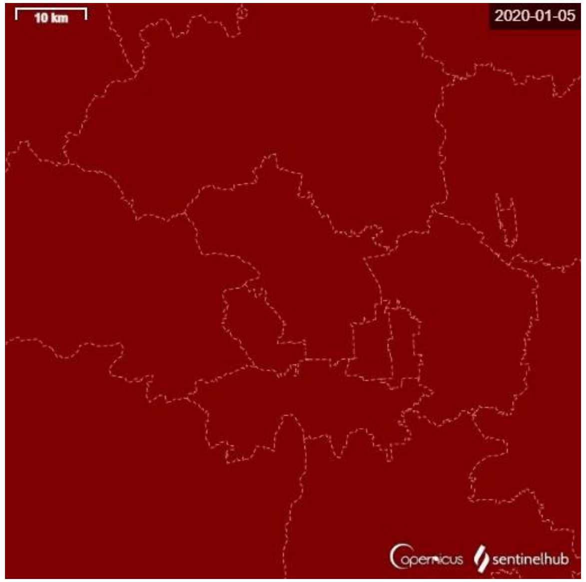
The large fluctuations in traffic during the COVID-19 pandemic provide an unparalleled opportunity to assess vehicle emission control efficacy. Here we develop a random-forest regression model, based on the large volume of real-time observational data during COVID-19, to predict surface-level NO_2, O_3, and fine particle concentration in the Los Angeles megacity. Our model exhibits high fidelity in reproducing pollutant concentrations in the Los Angeles Basin and identifies major factors controlling each species. During the strictest lockdown period, traffic reduction led to decreases in NO_2 and particulate matter with aerodynamic diameters <2.5 μm by –30.1% and –17.5%, respectively, but a 5.7% increase in O_3. Heavy-duty truck emissions contribute primarily to these variations. Future traffic-emission controls are estimated to impose similar effects as observed during the COVID-19 lockdown, but with smaller magnitude. Vehicular electrification will achieve further alleviation of NO_2 levels.

COVID-19 machine learning air pollution traffic emissions vehicular electrification

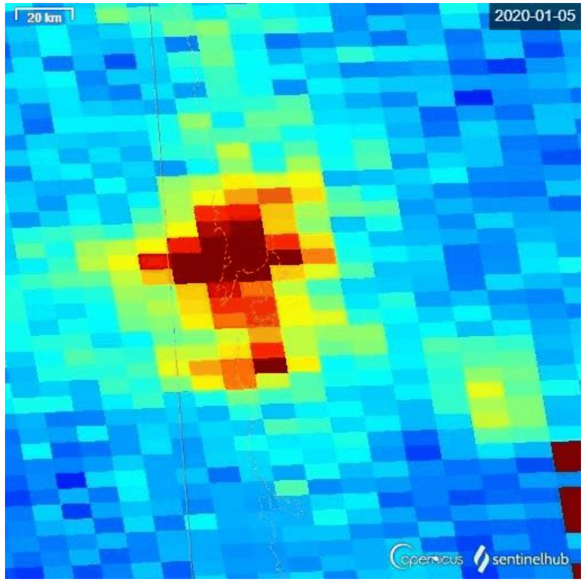
TROPOMI NO_2



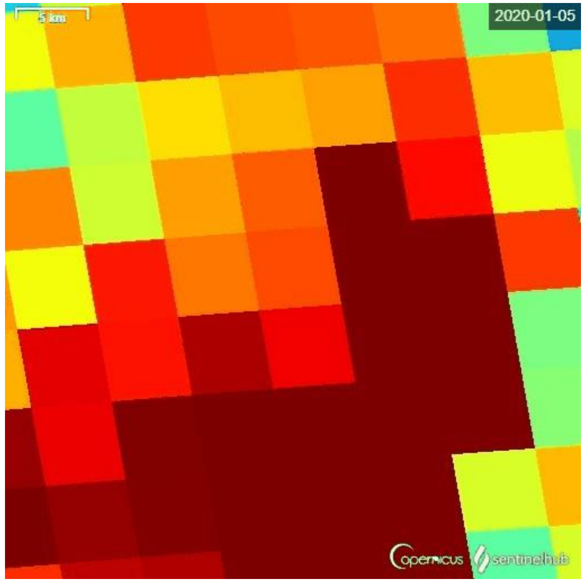
Los Angeles



Beijing-Tianjin-Hebei Area

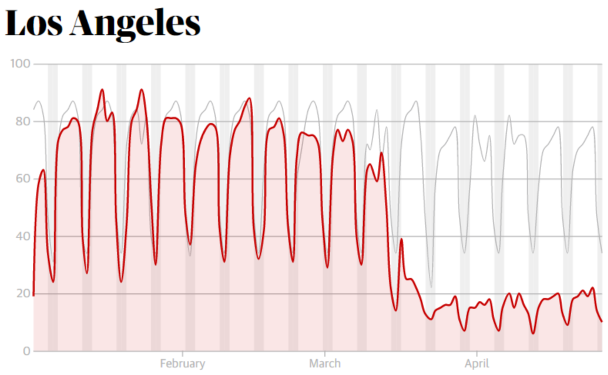


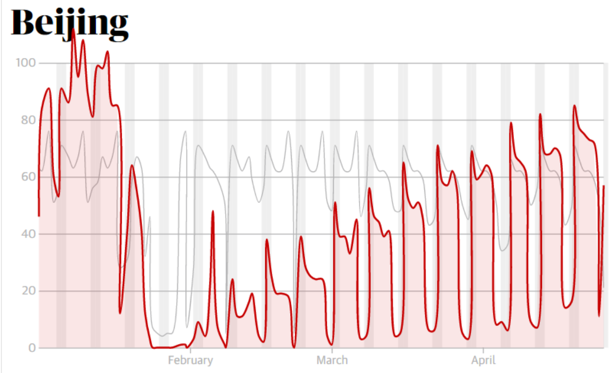
Mubai

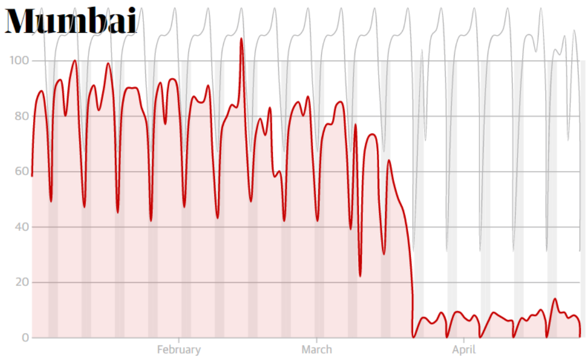


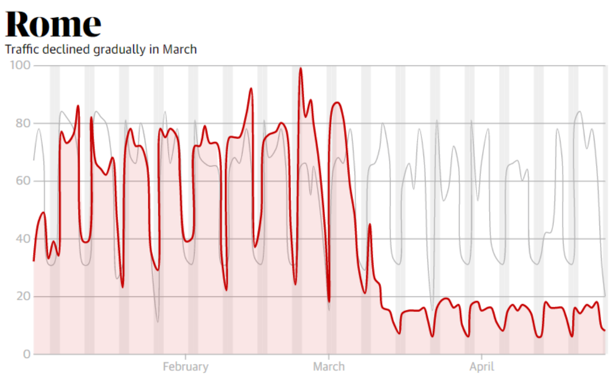
Rome

Traffic Change





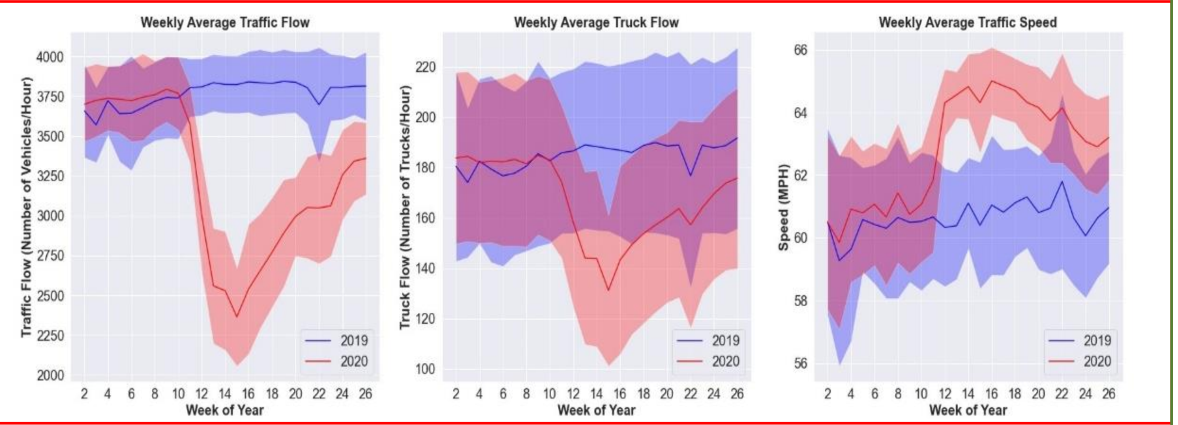


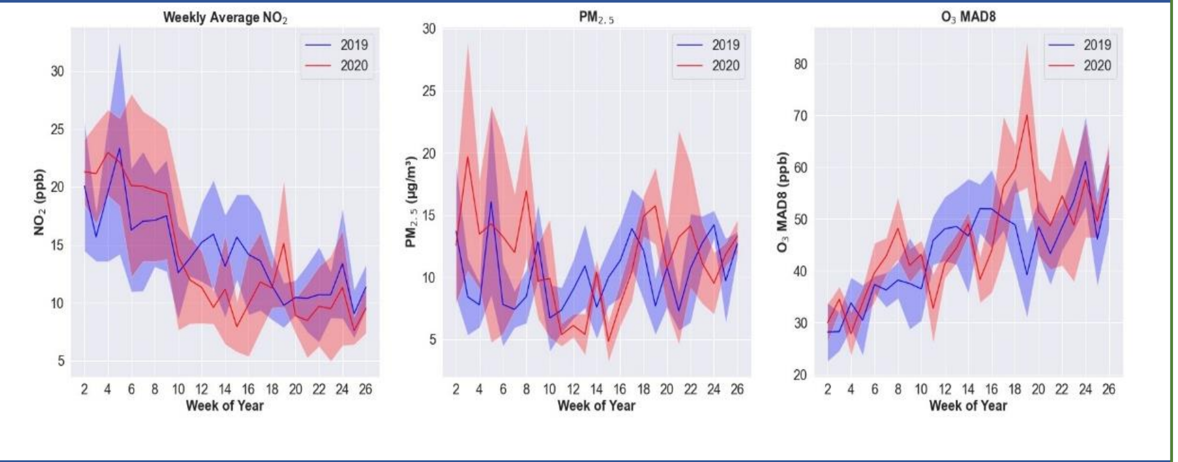


Data Source: TomTom

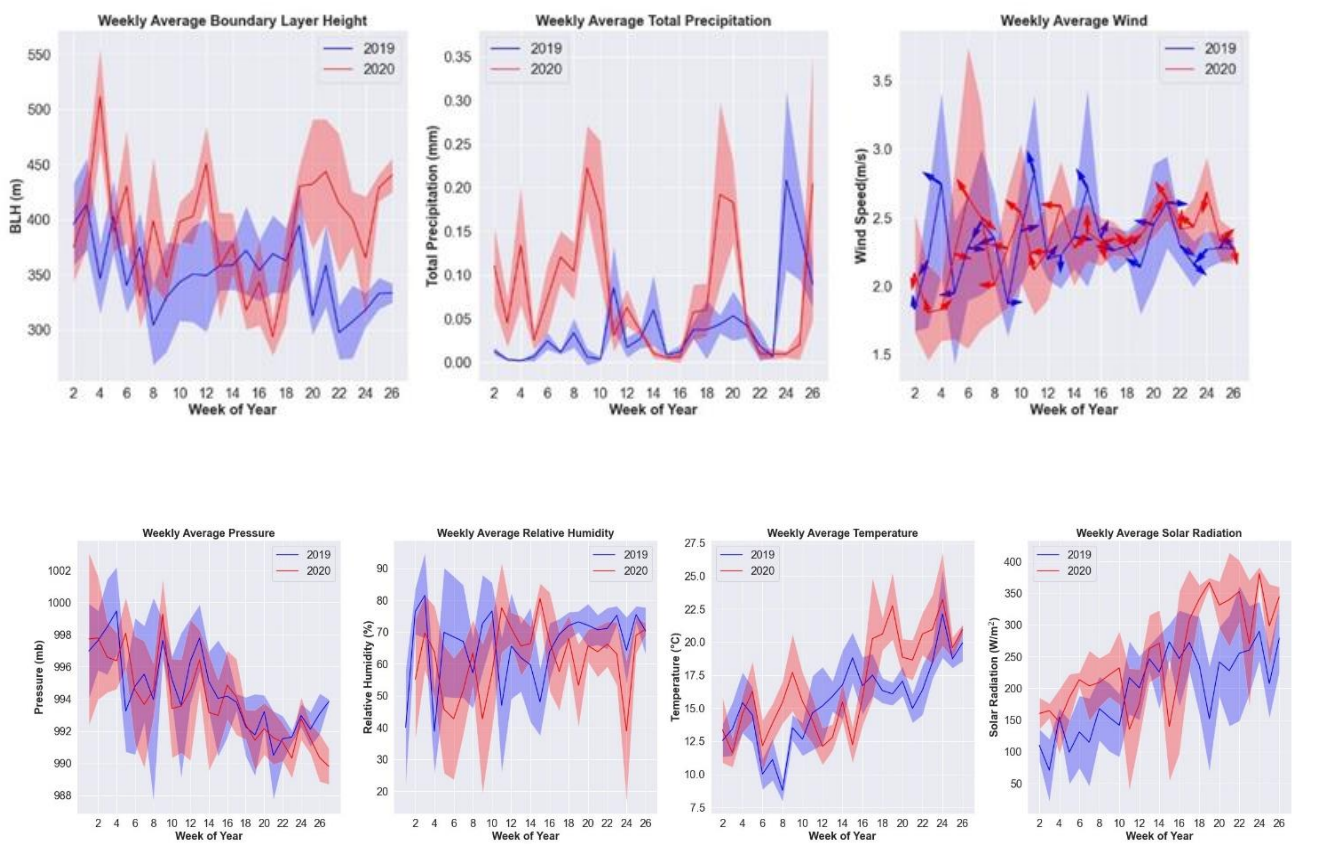
Observed Pattern in LA Traffic and Pollution During the COVID-19

Anthropogenic Emission





Chemical Reaction



Meteorological Transportation

Air Quality in China during COVID-19

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REPORT

Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China

Tianhao Le[1,*], Yuan Wang[1,*,†], Lang Liu[2,3,*], Jiani Yang[1], Yuk L. Yung[1], Guohui Li[2,3], John H. Seinfeld[4]

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Air pollution epidemic

The lockdown enforced in most cities in China in response to the outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) resulted in the virtual absence of motor vehicle traffic and sharply reduced manufacturing activity for several weeks. Le *et al.* report some of the anticipated and unanticipated effects that this had on air pollution there, including unexpectedly high levels of particulate matter abundances and severe haze formation in some areas. This natural experiment will help in the assessment of air pollution mitigation strategies.

Science, this issue p. 702

Abstract

The absence of motor vehicle traffic and suspended manufacturing during the coronavirus disease 2019 (COVID-19) pandemic in China enabled assessment of the efficiency of air pollution mitigation. Up to 90% reduction of certain emissions during the city-lockdown period can be identified from satellite and ground-based observations. Unexpectedly, extreme particulate matter levels simultaneously occurred in northern China. Our synergistic observation analyses and model simulations show that anomalously high humidity promoted aerosol heterogeneous chemistry, along with stagnant airflow and uninterrupted emissions from power plants and petrochemical facilities, contributing to severe haze formation. Also,

Le, T. *et al.* Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China. *Science* **369**, 702–706 (2020).

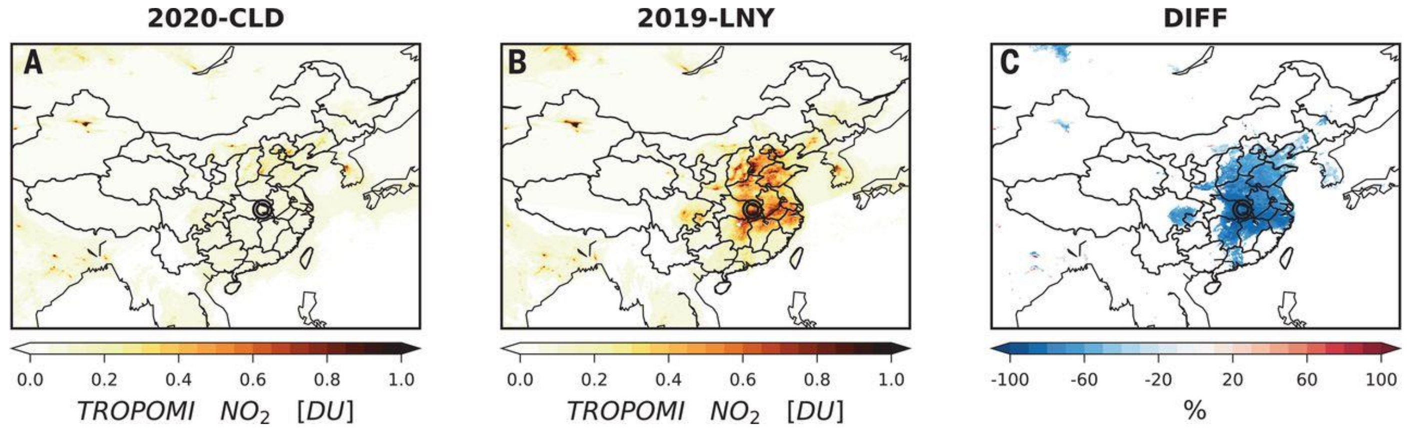


Fig. 1 Spaceborne measurements of NO2 from TROPOMI.

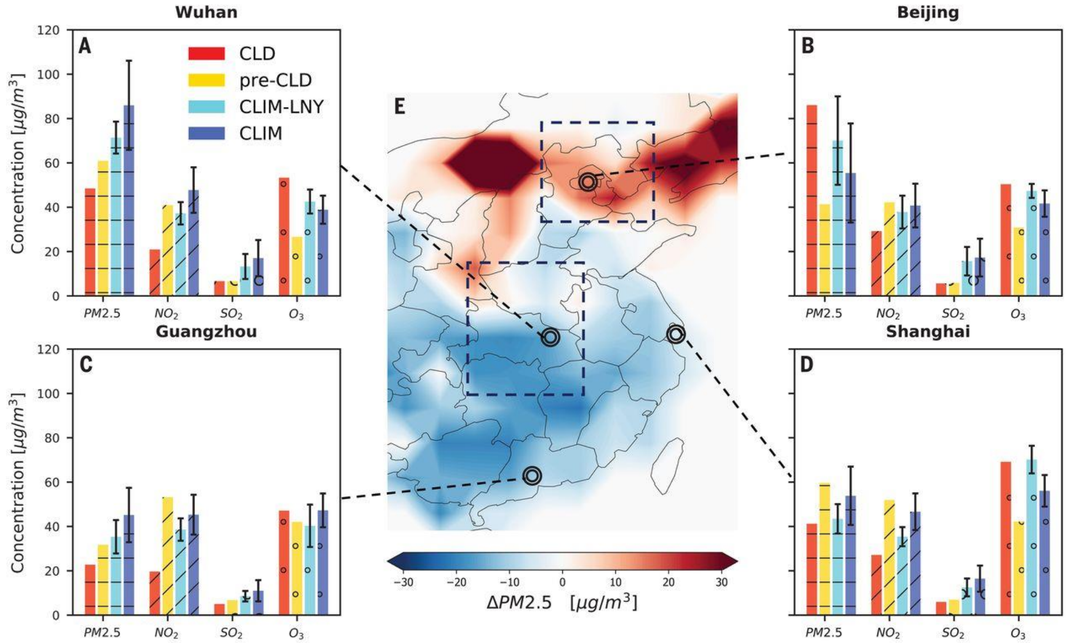
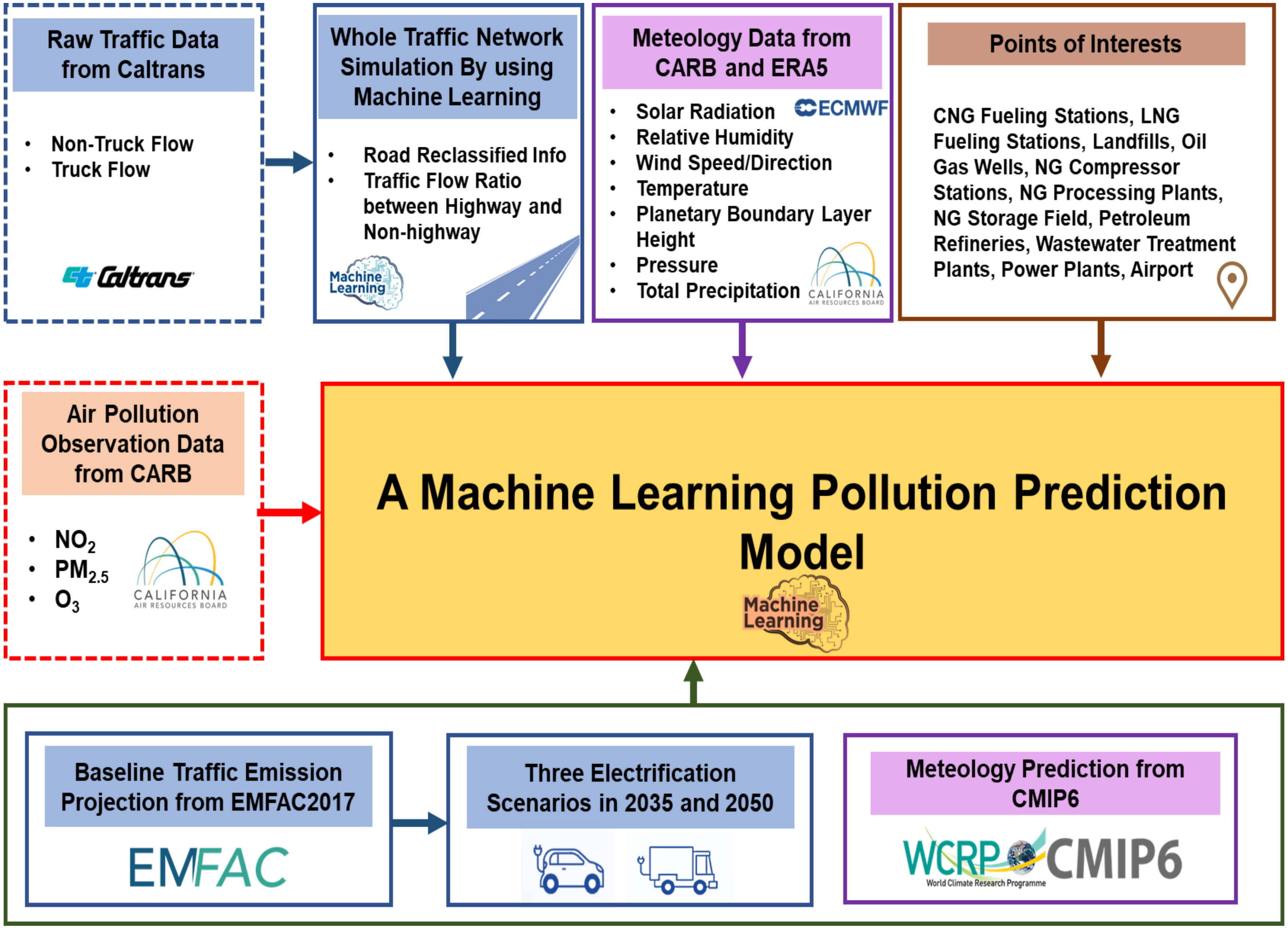


Fig. 2 Ground-based station observation of PM2.5, NO2, SO2, and ozone in eastern China, including four megacities..

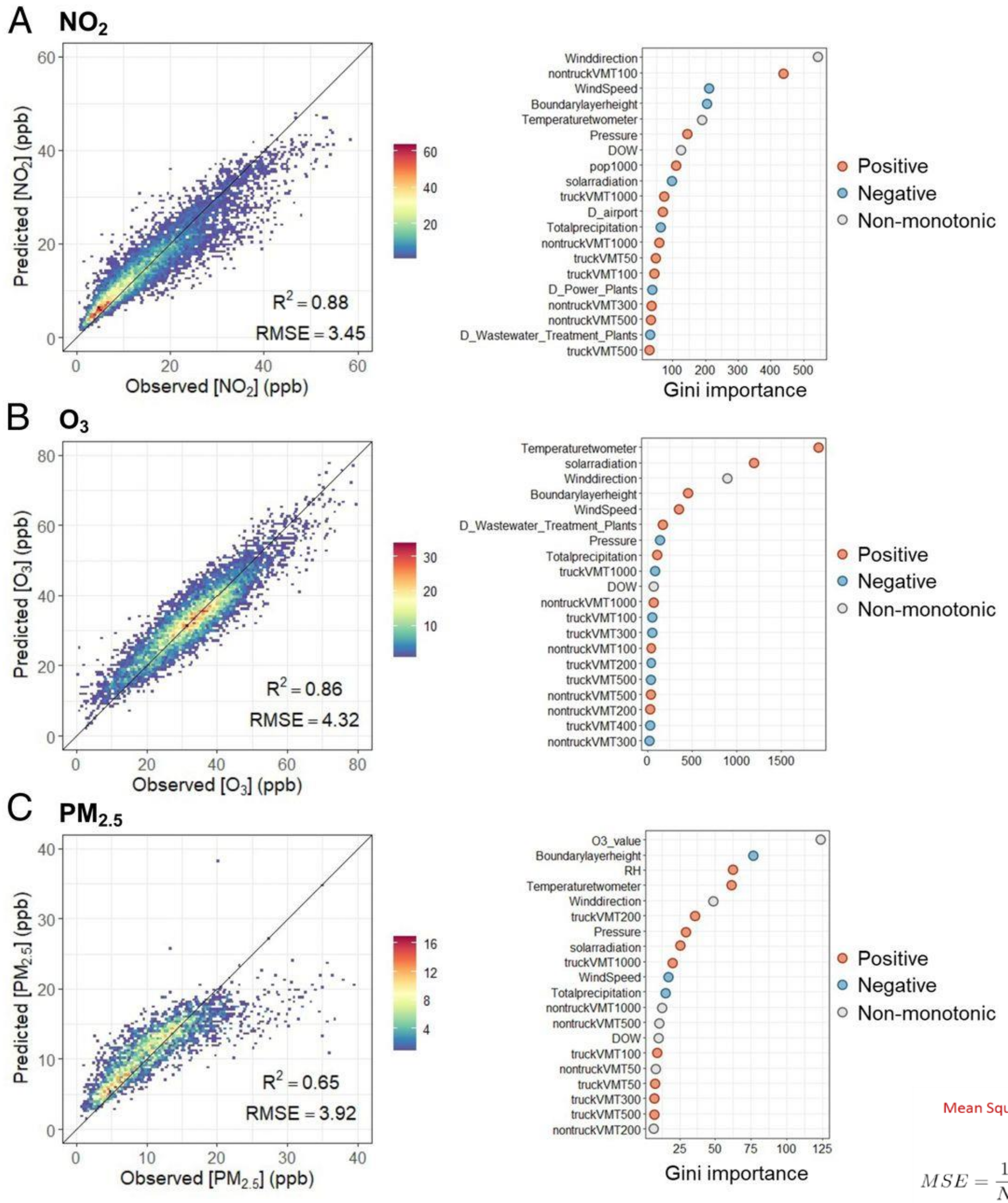
Methodology

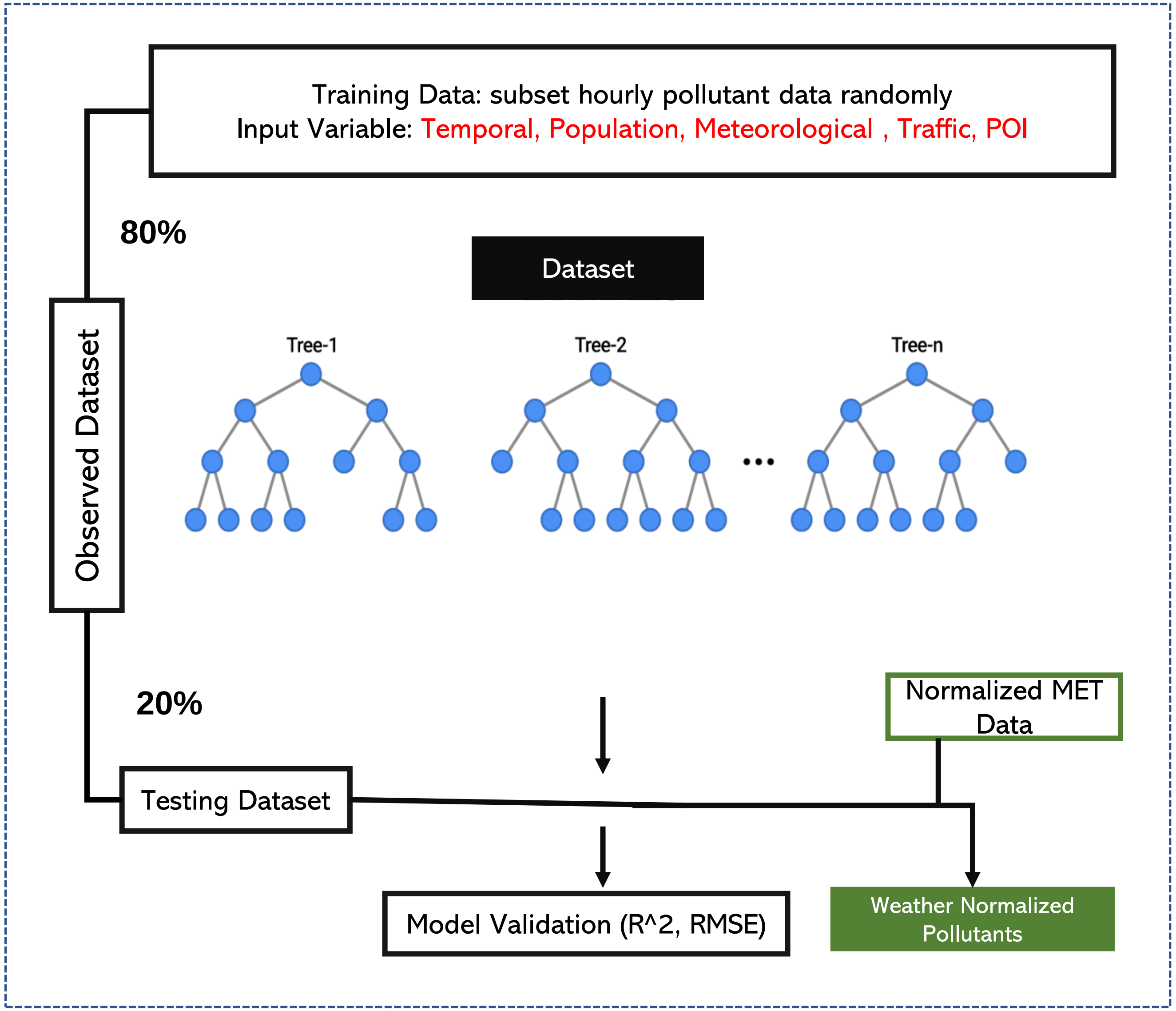


Random Forest model to predict air pollutants

- Predictors: $PM_{2.5}$, NO_2 and O_3 concentrations at air quality monitoring sites.
- Period: 1/1 - 12/31 in 2019 and 1/1 - 7/1 in 2020
- Indicators:
  - **Temporal parameters**: year (2019, 2020), day of the week (1-7), holiday;
  - **Population density in buffers** (persons/km^2);
  - Site-specific **meteorological parameters**: wind speed (m/s), wind direction (deg), temperature (°C), boundary height (m), precipitation (m), solar radiation, pressure, relative humidity (%);
  - **Traffic activity**: non-truck flow, non-truck VMT, truck flow, truck VMT in buffers.
  - Shortest distance to the nearby **POIs** (CNG/LNG Fueling Stations, Landfills, NG Compressor Stations, NG Processing Plants NG Storage Fields, Oil Gas Wells, Petroleum Refineries, Power Plants, Wastewater Treatment Plants, Airports, Ports)
- Configuration of Buffers: circles with radii of 50m, 100m, 200m, 300m, 400m, 500m, 1000m, 2000m, 3000m, 4000m, 5000m.

Machine Learning Prediction of Key Pollution Factors



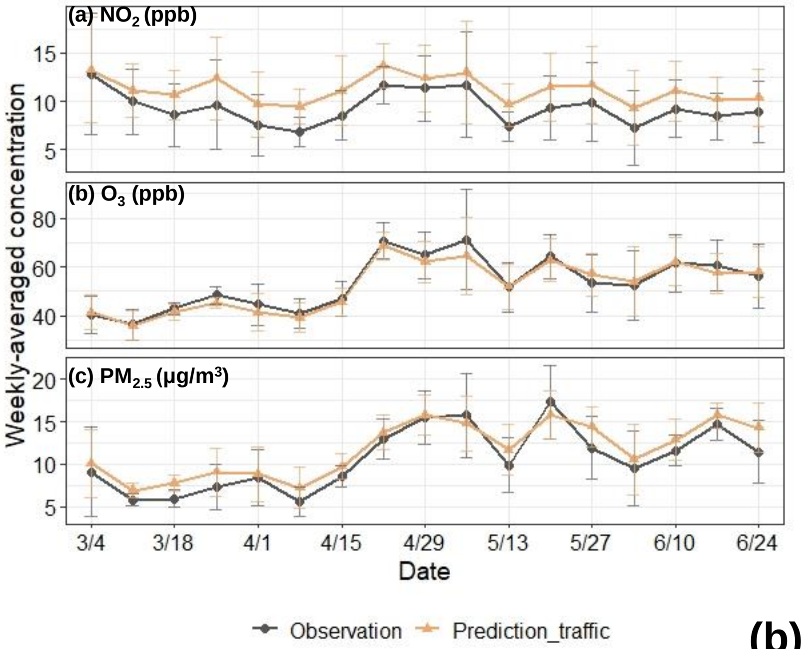


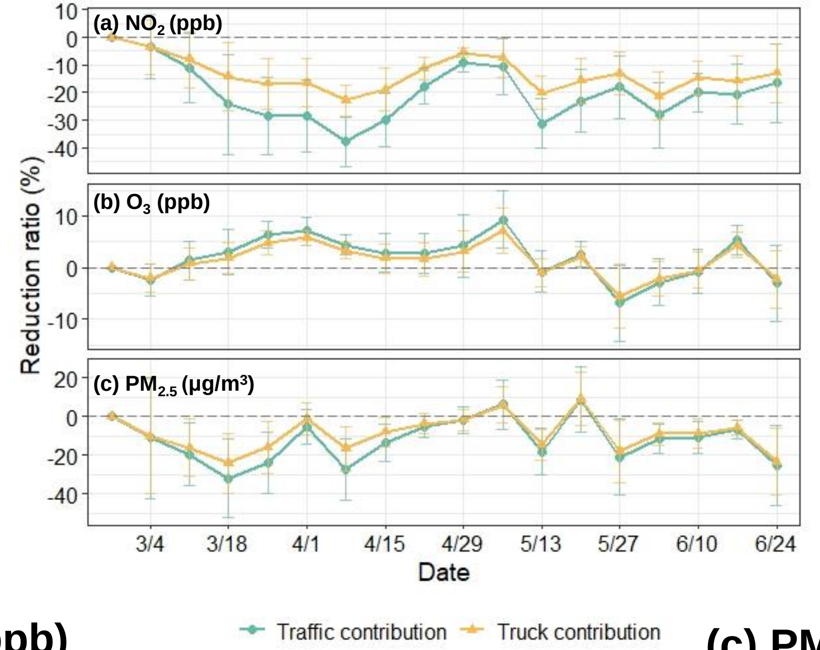
Mean Squared Error

$$MSE = \frac{1}{N}\sum(t_i - s_i)^2$$

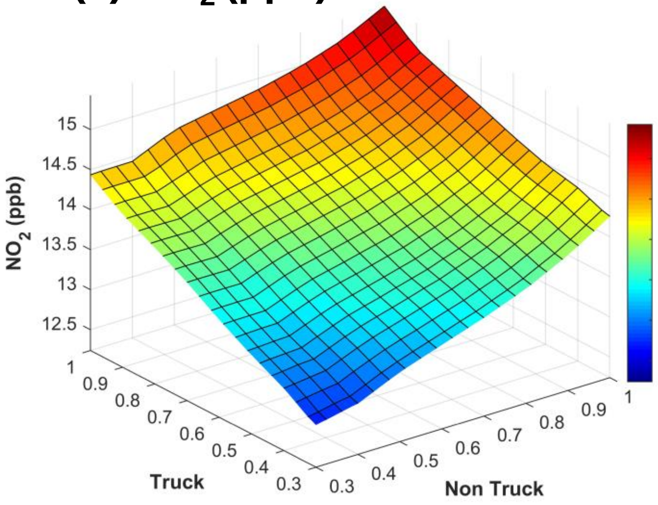
Prediction; Ground Truth

Simulated Traffic Impact on LA Air Pollution During COVID-19

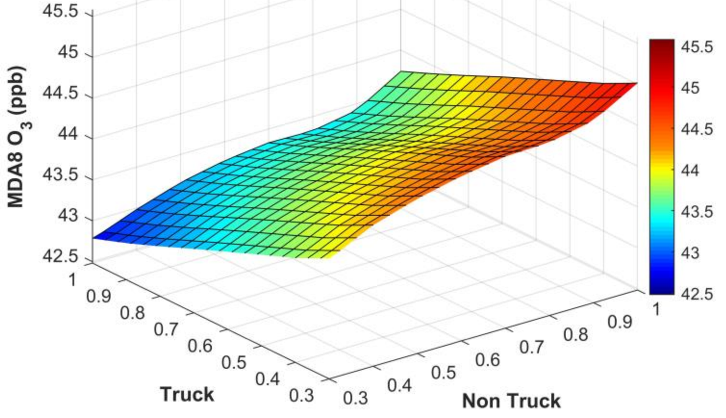




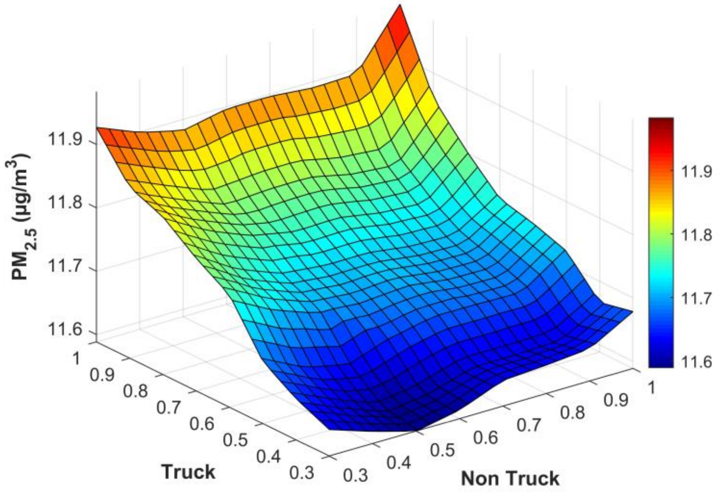
(a) NO_2 (ppb)



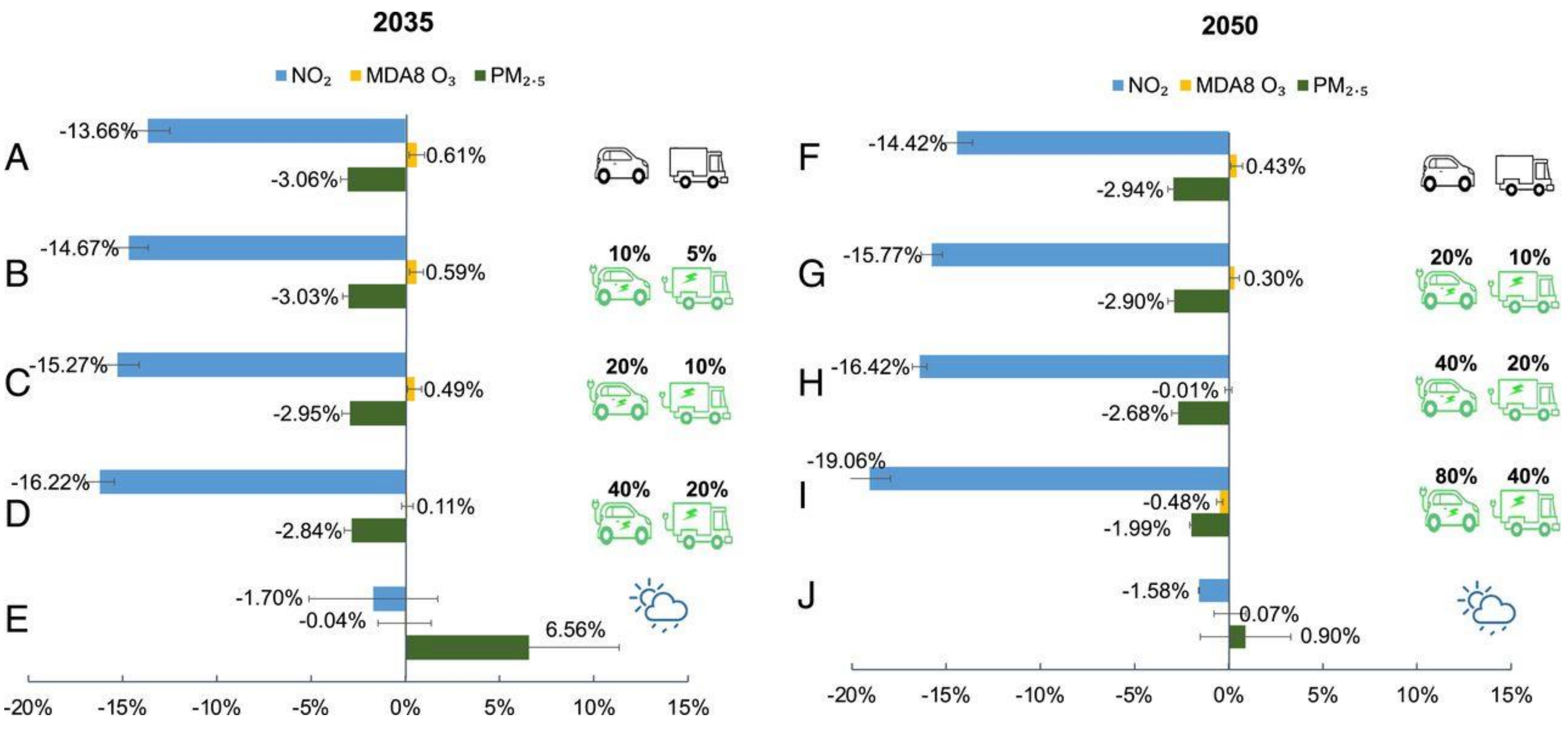
(b) O_3 (ppb)



(c) $PM_{2.5}$ (μg/m³)



Future Traffic and Climate Impact on LA Air Quality



Thank you!

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