Figure S1. Comparison of observed and interpolated PM$_{2.5}$ concentrations ([PM$_{2.5}$]) in China from 2015 to 2022. Panel (a) displays annual mean [PM$_{2.5}$] (μg m^{-3}) at 1822 monitoring sites. Panel (b) shows interpolated annual mean [PM$_{2.5}$] from Tracking Air Pollution (TAP) dataset. Panel (c) presents the difference between interpolated and observed values. Panel (d) compares annual mean [PM$_{2.5}$] at each site with observations, with colors indicating data frequency. Validation metrics, including sample size (N), regression equation, determination coefficient (R^2), root-mean-square error (RMSE), and mean absolute error (MAE) are also provided.
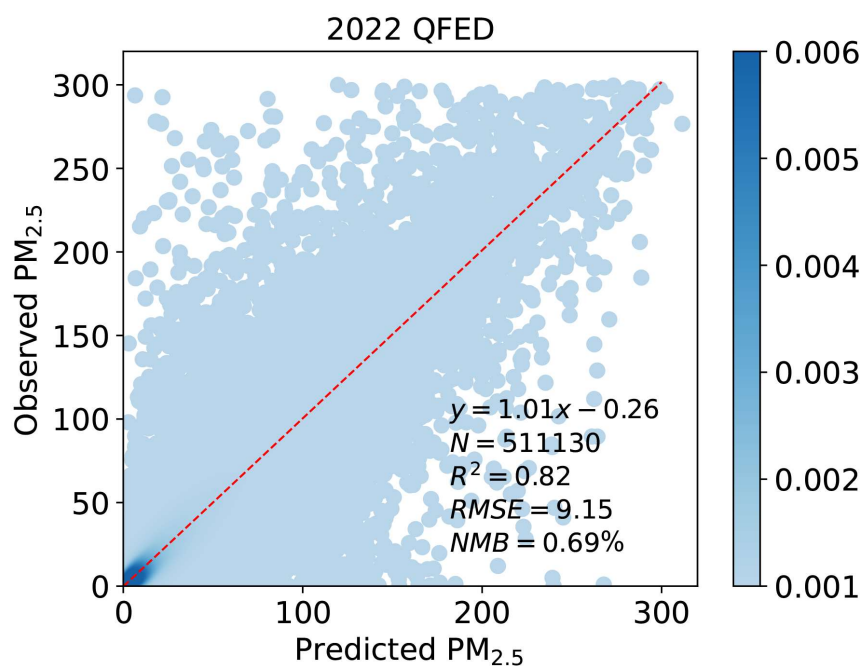
Figure S2. Same as Fig. 1b, but for GEOS-Chem simulations using the QFED inventory.
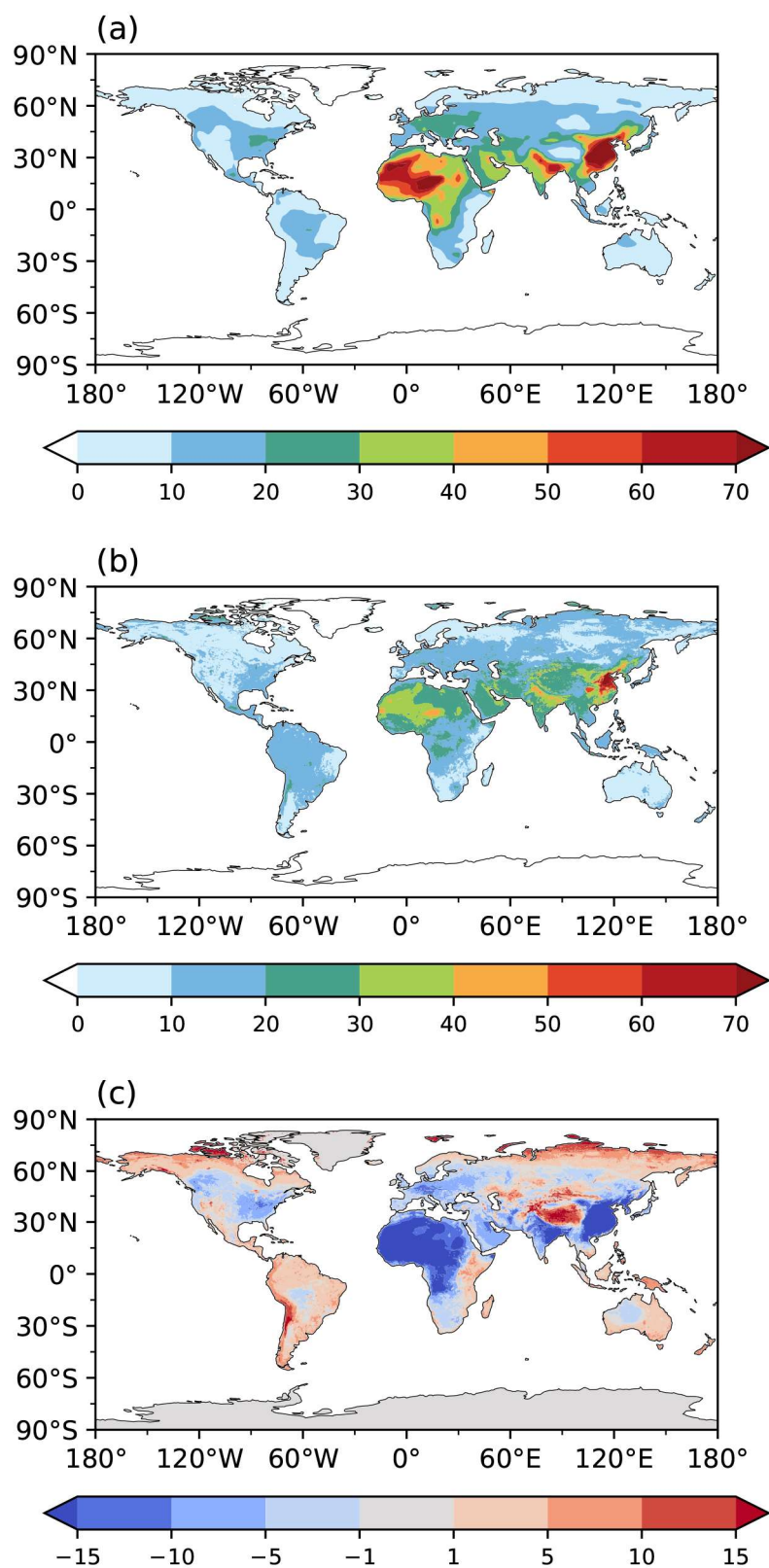
Figure S3. The same as Fig. 4 but with fire emissions from the QFED inventory.

NOAA HYSPLIT MODEL
Backward trajectories ending at 0400 UTC 15 Aug 18
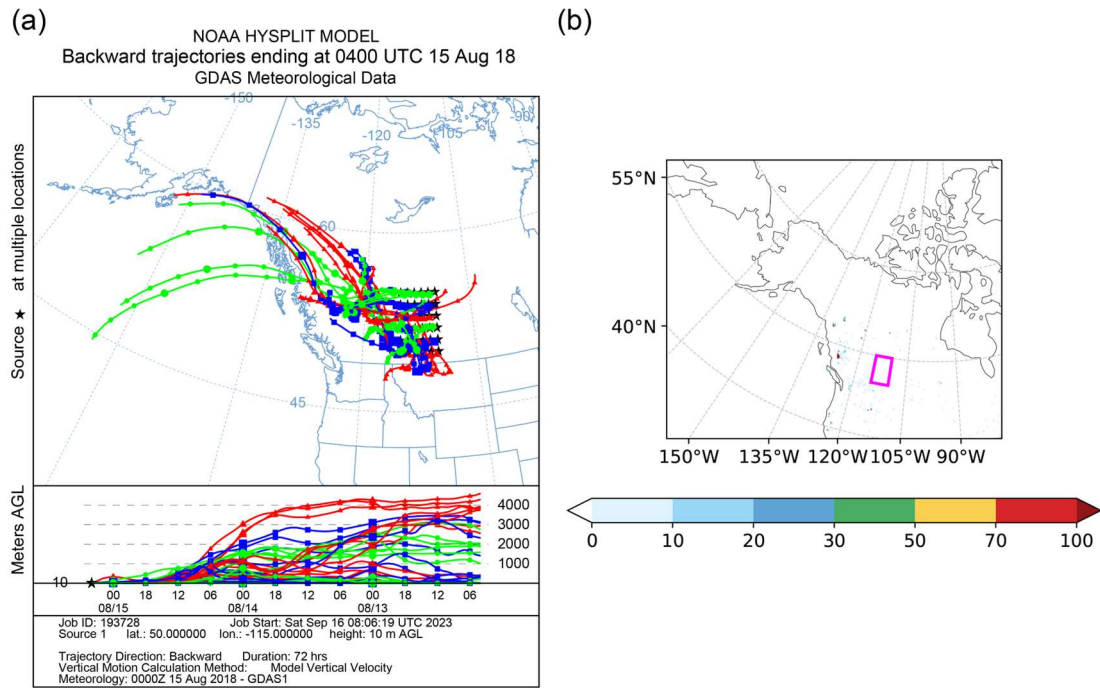### GDAS Meteorological Data

(b)

Figure S4. The 72-hour backward trajectories of Canadian sites ending on August 15th, 2018 , generated using the NOAA HYSPLIT Trajectory Model. The horizontal and vertical trajectories are shown in (a) and the fire emissions of GFED inventory averaged for August 13-15, 2018 are shown in (b). The pink box represents the range of sites in Canada.
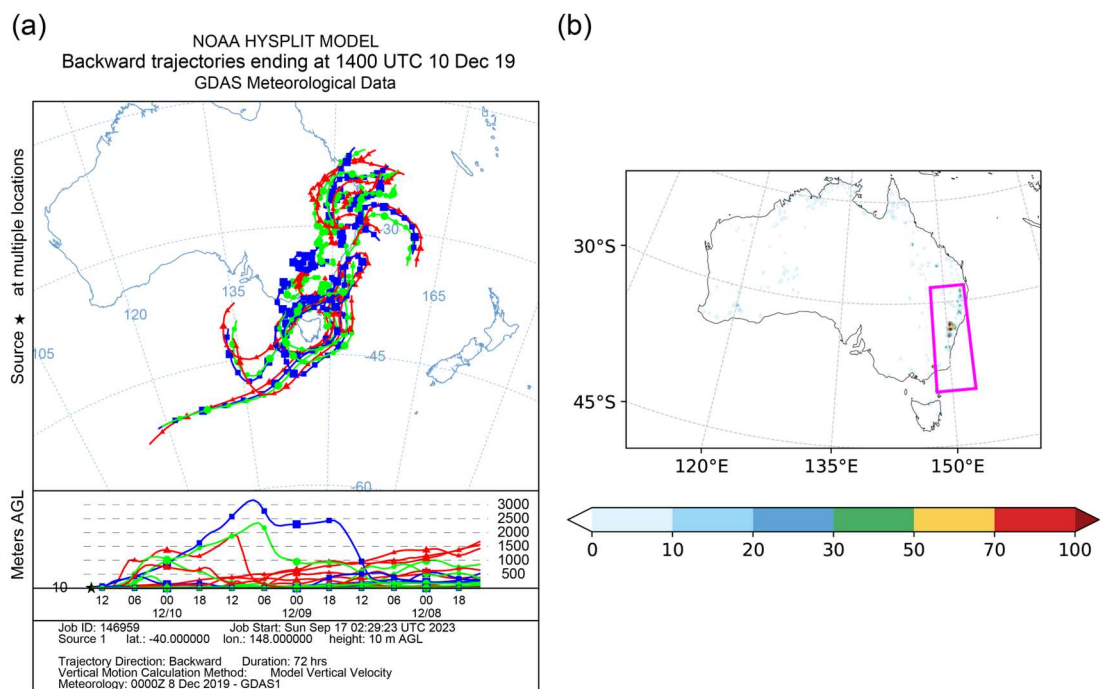
Figure S5. The same as Fig. S4 but for the backward trajectories of Australian sites ending on December 10th, 2019.
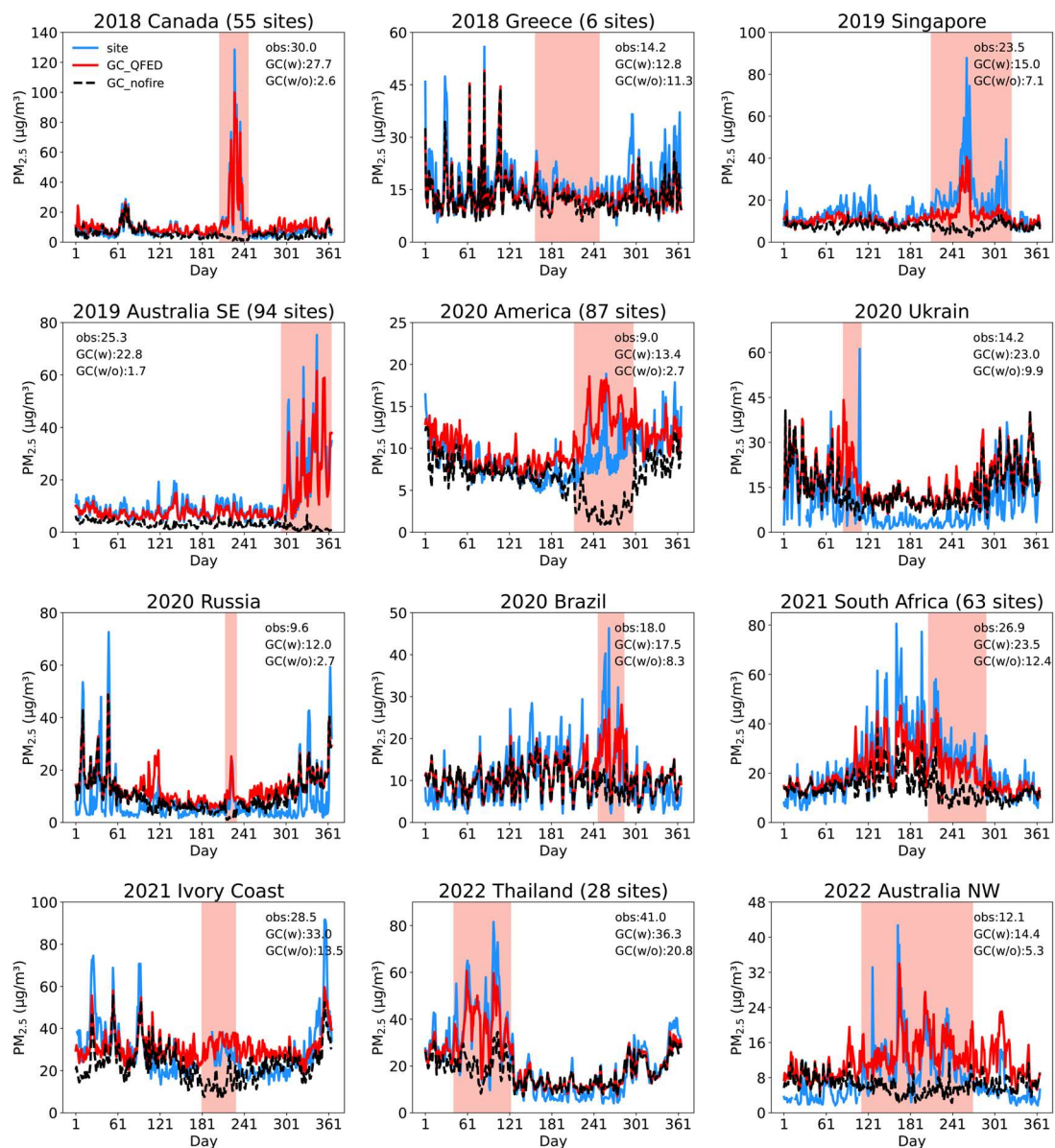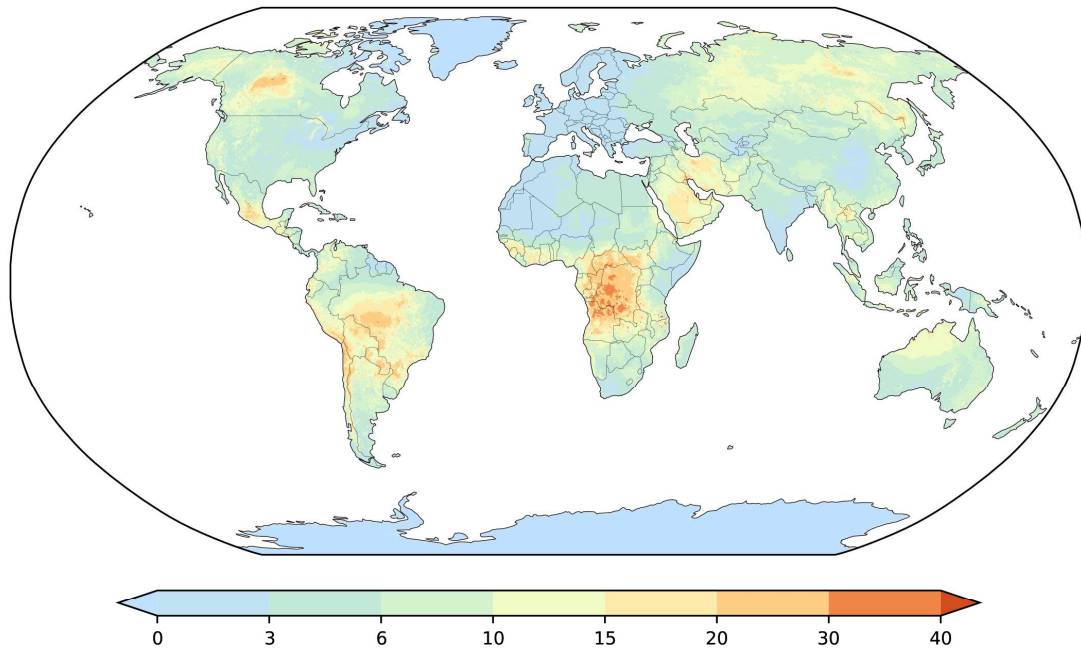
Figure S6. The same as Fig. 5 but the simulated [PM$_{2.5}$] is derived using QFED fire emission inventory.
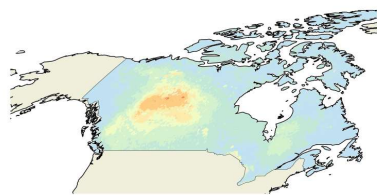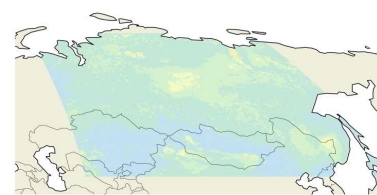
Figure S7. The same as Fig. 8 but with fire emissions from the QFED inventory.

Table S1 Summary of the input for machine learning model

Variables	Descriptions
GC_GFED	Simulated [PM$_{2.5}$] by GEOS-Chem using GFED emissions
GC_QFED	Simulated [PM$_{2.5}$] by GEOS-Chem using QFED emissions
BLH	Boundary layer height
Pc	Convective precipitation
Pls	Large scale precipitation
Pt	Total precipitation
T2M	2m temperature
T2X	Maximum 2m temperature since previous post processing
T2N	Minimum 2m temperature since previous post processing
RH	Relative humidity
SP	Surface pressure
SRD	Surface solar radiation downwards
T500	Temperature 500hPa
T850	Temperature 850hPa
TCC	Total cloud cover
V10M	Wind speed at 10m
V500	Wind speed at 500hpa
V850	Wind speed at 850hpa
F_Water	The cover fraction of Water
F_ENF	The cover fraction of Evergreen Needleleaf Forest
F_EBF	The cover fraction of Evergreen Broadleaf Forest
F_DNF	The cover fraction of Deciduous Needleleaf Forest
F_DBF	The cover fraction of Deciduous Broadleaf Forest
F_Mforest	The cover fraction of Mixed Forests
F_Cshrub	The cover fraction of Closed Shrubland
F_Oshrub	The cover fraction of Open Shrubland
F_Wsavanna	The cover fraction of Woody Savannas
F_savanna	The cover fraction of Savannas
F_grass	The cover fraction of Grasslands
F_Pwetland	The cover fraction of Permanent Wetlands
F_crop	The cover fraction of Croplands
F_urban	The cover fraction of Urban and Built-up
F_CVM	The cover fraction of Cropland/Natural Vegetation Mosaic
F_snow	The cover fraction of Snow and Ice
F_barren	The cover fraction of Barren or Sparsely Vegetated

Table S2 Spatiotemporal information of wildfire episodes

Event	Region	Time
2018 Canada	British Columbia	2018.7-2018.8
2018 Greece	Athens	2018.6-2018.8
2019 Singapore	Sumatra	2019.8-2019.11
2019 Australia SE	New South Wales	2019.10-2019.12
2020 Ukrain	Chernobyl	2020.3-2020.4
2020 Russia	Siberia	2020.8
2020 Brazil	Sao Paulo	2020.9-2020.10
2021 Ivory Coast	Yamoussoukro	2021.7-2021.9
2021 South Africa	Limpopo	2021.7-2021.10
2022 Australia NW	Northern Territory	2022.4-2022.9
2022 Thailand	Lampang	2022.4-2022.5