Data Organization and Operating Procedures

Revision 15, June 14, 2022

Overview/Purpose and Included Data

The purpose of this document is to describe the collection, processing, and management of exposure data for a variety of US-based air pollution model development tasks and their associated environmental epidemiology studies. The primary aims are: 1) to record the treatment of all of the Kaufman Lab's environmental monitoring data prior to its upload to the Exposure Assessment Core's (EAC) database; 2) to describe the content and processing of third-party (e.g., Air Quality Systems, NYCCAS) data; and 3) to describe the data request process. Health data are collected and stored at study-specific coordinating centers, and documentation for these data handling procedures can be found in a separate Standard Operating Procedure (SOP) document. **The EAC does not fill data requests for health data.** We are currently distributing data from Revision 15 (Rev 15) of the EAC Database. The data available in Rev 15 include:

<u>Location data</u>

Location identifiers for monitoring sites and participant homes include: county according to the 2000 Census, state, metropolitan statistical area as of the year 2000 and CBSA as of the year 2010, census tract, block group, and block according to years 2000 and 2010 censuses, projected coordinates [x,y] referenced to the national US Conical Lambert projection in meters, latitude and longitude in decimal degrees.

- **Residential Locations**
  - Address histories for the following cohorts: MESA Air, SPIROMICS Air, The Sister Study, Two Sister Study, GEMS, the Cardiovascular Health Study (CHS), REGARDS
  - Address locations (geocodes), not time-resolved and potentially including QC locations for the following cohorts: 2019 update for the Women's Health Institute Observational Study and Clinical Trial (WHI-OS and CT), ACT-AP
- **Air Monitoring Locations and Weather Stations**
  - AQS (state and local) and IMPROVE (federal) monitoring network sites
  - New York City Community Air Survey (NYCCAS) monitoring sites
  - Inhalable Particle Network (IPN) sites
  - Various DEOHS projects, including MESA Air, Diesel Exhaust Exposure in the Duwamish Study (DEEDS) monitoring sites, CCAR, SPIROMICS Air, ACT AP and others
  - NOAA meteorological monitoring stations throughout the continental US
- **Other Locations**
  - Grids for map-making
  - Year 2010 Census Tract centroids

<u>Exam Dates</u>

- The following exams for MESA Air participants: clinical exams, Computed Axial Tomography (CT) scans, magnetic resonance imaging (MRI) scans, ultrasound scans, and spirometry. We don't distribute the dates directly but can provide air pollution exposures referenced to them.
- Clinical exams SPIROMICS Air participants
- Clinical exams for CHS participants

<u>Federal, State, and Local Agency Monitoring data</u>

AQS, Speciation Trends Network (STN), and IMPROVE monitoring data are available throughout the lower 48 United States. The years for which data are available for specific pollutants are variable, as regulatory needs have changed over time. The last date for which data are available varies by location

and depends on the diligence with which agencies report updates. In general, AQS and STN data are considered up-to-date through mid-2021 for most locations. IMPROVE data are available from March 1988 through December 2020 for $PM_{2.5}$ and its species. Specific availability by pollutant is as follows:

- AQS monitoring data for NO_2, NO_X, SO_2, O_3, and CO beginning in 1980
- AQS monitoring data for PM_{10} beginning in 1983 and IMPROVE monitoring beginning in 1999
- AQS monitoring data for $PM_{2.5}$ beginning in 1999, IMPROVE monitoring data beginning in 1988
- AQS monitoring data for sulfate (SO_4^{2-}) and nitrate (NO_3^-) beginning in 2000
- STN monitoring data for elemental carbon and organic carbon (EC/OC) beginning February 2000, IMPROVE monitoring data for EC/OC beginning March 1988
- STN and IMPROVE monitoring data for selected elemental species (aluminum, arsenic, bromine, cadmium, calcium, chromium, cobalt, copper, iron, potassium, manganese, sodium, silicon, selenium, sulfur, nickel, vanadium, and zinc) beginning in 1988
- IPN monitoring data for $PM_{2.5}$, PM_{15}, $PM_{15\text{-}2.5}$, and PM_{30} between 1979 and 1982

<u>Air quality data collected through MESA Air and related studies</u>

- $PM_{2.5}$, $PM_{2.5}$ species, NO_X, NO_2 and O_3 data collected as part of MESA Air and the Health Effects Institute (HEI) / National Particle Components Toxicity (NPACT) study
- $PM_{2.5}$, NO_X, NO_2 and O_3 monitoring data collected as part of the SPIROMICS Air Study
- $PM_{2.5}$ and NO_X monitoring data collected as part of DEEDS
- NO_X monitoring data collected in Yesler Terrace
- NO_X monitoring data collected under the LAX approach flightpath
- $PM_{2.5}$, PM_{10}, $PM_{10\text{-}2.5}$, associated elemental species, and endotoxin monitoring data collected as a part of the MESA Coarse PM Study
- NO_X and O_3 Ogawa badge data collected at 'fuzzy points' in Atlanta, Baltimore, LA, Winston-Salem, and St. Paul by CCAR Project 1
- NO_X, O_3, and VOC badge data collected at residential locations and in vehicles in Winston-Salem and LA as part of CCAR Project 5
- $PM_{2.5}$, NO_X, NO_2 and O_3 monitoring data collected as part of the ACT-AP Study
- $PM_{2.5}$, NO_X, NO_2 and O_3 monitoring data collected as part of the MESA Air R56

<u>Exposure model outputs – region-specific</u>

- $PM_{2.5}$, NO_X, NO_2, and O_3 predictions for the years 1999 – 2018 at 2-week resolution in MESA Air and SPIROMICS Air cities
- Indoor $PM_{2.5}$, NO_X, NO_2, and nicotine for the subset of SPIROMICS addresses with Home Information Questionnaire data
- LAC predictions for MESA Air participants' addresses in the MESA Air areas representing long-term exposure (predictions averaged over 2006 – 2008) and at two-week resolution (2005 – 2009)
- Land use regression predictions for $PM_{10\text{-}2.5}$ and silicon, copper, zinc, and phosphorus in the coarse fraction for MESA Air participants' addresses in the MESA Coarse Study monitoring areas (Chicago, Winston-Salem, and St. Paul)

<u>Exposure model outputs – National Models (Continental US, Annual Averages)</u>

- $PM_{2.5}$ predictions for each year from 1999 – 2015
- $PM_{2.5}$ predictions for each year from 1980 – 2010 from an annual spatio-temporal model ("historical PM2.5 model")
- PM_{10} predictions for each year from 1990 – 2016
- NO_2 predictions for each year from 1990 – 2014

- K-means cluster predictions

Exposure model outputs – National Spatiotemporal Models (Continental US, every 2 weeks)

- $PM_{2.5}$ predictions for 1999 – 2019
- NO_2 and O_3 predictions for 1990 – 2020

Meteorological data

- Visibility, temperature, wind speed, wind direction, humidity, sea level pressure, station-level pressure and ceiling height data at the daily time scale at meteorological stations throughout the nation from the years 1980 – 2021.
- The meteorological data is downloaded from the following NOAA source: https://www.ncei.noaa.gov/data/local-climatological-data/archive

Geographically-linked data

- Geographic covariate values
    - USGS aerial photography-based land use in buffers, year 2006 satellite-based land use in buffers, impervious surface, normalized difference vegetative index (NDVI), distance to features, emissions in buffers, sum of road lengths in a buffer, sum of truck route lengths in a buffer, counts of intersections in buffers, population in buffers, and elevation nationally
    - Distance to nearest residual oil source, sums of oil emissions in buffers, nearest bus route, and sum of bus routes in buffers for the New York City area
    - Urban topography for locations in New York City and Chicago
- Selected census variables for all block groups, blocks, and tracts in the lower 48 United States for both Census 2000 and Census 2010
- Average column NO_2 for the year 2006 at census block centroid as measured by satellite image processing
- Average column NO_2 for a Moore neighborhood of pixels near each location in the continental US for the years 2005 – 2007
- Vehicle emissions model outputs (MOVES data) by month for the years 1990 and 1999 – 2012.

Additional data will be added in future releases of the database. Planned updates are slated to include:

- Additional updates of existing models (e.g., national spatiotemporal models), are expected, both to incorporate additional AQS data not currently available and to reflect improvements to modeling methodology.
- Updated bus and truck routes
- Locations according to year 2020 census

Database revisions are planned to occur approximately once per year. If the available data does not satisfy the needs of a particular analysis, data users are encouraged to contact the EAC as soon as possible to negotiate new data's inclusion in an upcoming revision.

1. Sources, Contents, and Quality Control of Data

1.1. Overview of Location Data

Location data are central to the design of the EAC mySQL database, as all exposure data compiled for the relevant studies are associated with a location and all exposure predictions will be made at locations. Locations of interest include air quality monitoring sites, meteorological monitoring sites, and participants' homes. Other important locations include the intersection points of grids developed at various scales to facilitate preparation of visual aids like concentration maps. "Location data" refers to the data necessary to specify a position and its relevant characteristics. For example, a participant's home is located at a certain latitude and longitude. The latitude and longitude can then be used to determine geographic variables, such as population density at that location according to a given Census year. The coordinates of each location were determined as specified in each relevant subsection.

1.1.1. Map Projections and Coordinates

Geographic coordinates and projected coordinates are stored in the EAC database for all locations. Latitude and longitude are stored as decimal degrees as referenced to the North American Datum geographic coordinate system. Two different sets of projected coordinates will be available. The projected coordinates (x,y) represent the number of meters that the location lies from the origin of the projection. One set of coordinates will be referenced to a specific State Plane Zone. Another set of coordinates will be referenced to the US Conical Lambert projection (lambert x, lambert y). Distance calculations using State Plane coordinates are expected to be more accurate, but these coordinates cannot be used to calculate distances across State Plane Zones. Distances calculated between two points within a state plane could vary up to almost 1% depending on the coordinate system used (up to approximately 2 kilometers absolute distance).

Locations were assigned latitudes and longitudes ("geocoded") in one of three ways: created in ArcGIS from street addresses, recorded directly from digital global positioning system (GPS) units, or acquired directly from a third-party data provider. The geographic coordinates were then projected into the State Plane Coordinate System (SPCS). The latitude and longitude and the projected coordinates of the SPCS for participants' residences are available to users with appropriate permission. Coordinates that uniquely identify a participant's home are considered identifying information by the University of Washington Human Subjects Review Board. Access to participant home locations may be granted by the Principal Investigator for data users that demonstrate a need for that information, complete any relevant human subjects training, and sign or are supervised by someone that has signed the Data and Materials Distribution Agreement (DMDA).

1.1.2. Political Identifiers – County, State, Census Geometries

Political identifiers of location that are available include state, county, tract, block group, and block. Counties and year 2000 geometries are assigned by a spatial join to the TeleAtlas Dynamap 2000 v. 16.1 county shapefile. The year 2010 geometries are assigned by a spatial join to the year 2010 TIGER file.

The term 'city' is vague in the context of our health studies and is to be avoided, although we are able to provide the year 2000 Metropolitan Statistical Area (MSA) for locations. For convenience, a standard set of monitors were selected in each MESA Air study area for exposure modeling. These are indicated on the maps on the internal website.

1.2. Air Quality System (AQS) Data

1.2.1 Description of Data Source

Air quality data, *i.e.* pollutant concentrations, are collected nationally by networks of federally- and locally-funded agencies, called the Air Quality System (AQS). The AQS data from most agency monitoring locations were obtained from the Environmental Protection Agency's (EPA) website at https://aqs.epa.gov/aqsweb/airdata/download_files.html. Monitoring data from national parks and some rural locations is collected by a specific sub-network of the AQS, called the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Data collected by the IMPROVE network were obtained from the Visibility Information Exchange Web System (VIEWS), at http://views.cira.colostate.edu/iwdw/QueryWizard/Default.aspx. Users should be aware that non-IMPROVE monitoring locations are generally selected to assess population exposures, and that IMPROVE monitoring locations are generally selected to assess pollution impacts in sparsely populated environments. Therefore, users may determine that IMPROVE monitors are not representative of pollutant levels to which "nearby" subjects are exposed if those subjects live in reasonably populous areas.

The AQS network is comprised of a heterogeneous mixture of state, county, and local agencies throughout the United States. As funding availability and monitoring aims evolve, monitors come online or are discontinued, and monitoring schedules are altered. The monitors near a given location that collected $PM_{2.5}$ data from 2000 to 2002 may not have collected $PM_{2.5}$ data from 2003 to 2005. Furthermore, an individual monitor that collected $PM_{2.5}$ data every day in 2002 may have collected data every third day in 2003. Another monitor that collects $PM_{2.5}$ data every day during the winter may only collect data every third day in the summer. These features of the data primarily affect analysts creating exposure models. In general, health analysts conducting analyses based on AQS monitoring data will receive data from monitors as described in Sections 2.6 and 2.7.

$PM_{2.5}$ data is collected by air quality agencies via several methods, and is consistently reported in units of $\mu g/m^3$. Federal Reference Methods (FRM) are used to determine compliance with National Ambient Air Quality Standards (NAAQS). These data are considered to be of the most reliable quality, so only $PM_{2.5}$ data collected by FRM monitors will be available in the EAC database. FRM methods are similar to one another, and involve collecting $PM_{2.5}$ on a filter for 24 hours at a time. Most commonly, agencies measure $PM_{2.5}$ one out of three days, with occasional data loss. The IMPROVE network collects PM data using FRM-type methods. A comparison of IMPROVE data to AQS FRM data collected concurrently at the same locations indicated that these methods were comparable enough to be considered equivalent. Occasionally, EPA audits of AQS data have found that measurement conditions did not meet the specifications required to validate those measurements for regulatory purposes. Many of these measurements were re-classified as "raw data" by the EPA. Although there is some evidence that these data are noisier than validated measurements, they are collected using reference methods and EPA staff believe that they are "potentially of quality." We have included these measurements with a flag where no validated measurement was available. We can also provide data from Federal Equivalent Methods (FEMs). These include tapered element oscillating monitors (TEOMs) and beta attenuation monitors (BAMs), which are both one-hour integrated methods. When used for compliance purposes, these monitors are used alongside and corrected to filter methods. Uncorrected methods are not as well-correlated with the filter methods and some show seasonal bias. They are provided as-is and at users' own discretion.

We note that some agencies may operate two monitors concurrently at the same location for quality control purposes. The EAC database is intended to house no more than one concentration for a single point in time and space. Therefore, AQS monitoring methodologies were ranked in terms of reliability based on best professional judgment. A detailed list of the rankings can be found in Tables 1 through 5. Data for the more reliable monitor was retained for time periods during which two monitors' data were available from exactly the same location. If two co-located monitors used the same method, the data from the monitor with a more complete time series were retained. The alternative monitor's data were inserted for time periods during which only that monitor's data were available. Thus, a given location could have a single time series of monitoring data sourced from more than one monitor.

Table 1. Ranking of $PM_{2.5}$ collection methods

Rank	Method Code	Method Description
1	145	R & P Model 2025 $PM_{2.5}$ Sequential Air Sampler w/VSCC
2	118	R & P Model 2025 $PM_{2.5}$ Sequential w/WINS
3	144	R & P Model 2000 $PM_{2.5}$ Audit Sampler w/VSCC
4	143	R & P Model 2000 $PM_{2.5}$ Air Sampler w/VSCC
5	117	R & P Model 2000 $PM_{2.5}$ Sampler w/WINS
6	116	BGI Model PQ200 $PM_{2.5}$ Sampler w/WINS
7	155	Thermo Electron Model RAAS2.5-300 Sequential w/VSCC
8	142	BGI Models PQ200-VSCC or PQ200A-VSCC
9	129	R & P Model 2000 $PM_{2.5}$ Audit w/WINS
10	153	Thermo Electron Model RAAS2.5-100 w/VSCC
11	154	Thermo Electron Model RAAS2.5-200 Audit w/VSCC
12	135	URG-MASS100 Single $PM_{2.5}$ Sampler
13	136	URG-MASS300 Sequential $PM_{2.5}$ Sampler
14	128	Andersen RAAS2.5-2000$PM_{2.5}$ Aud w/WINS
15	119	Andersen RAAS2.5-100 $PM_{2.5}$ SAM w/WINS
16	120	Andersen RAAS2.5-300 $PM_{2.5}$ SEQ w/WINS
17	123	Thermo Env Model 605 CAPS [Computer Assisted Particle Sampler]
18	177	Thermo Scientific Partisole 2000-D Dichot.
19	179	Thermo Scientific Dichot. Partisole-Plus Model 2025-D Seq

Table 2. Ranking of PM_{10} collection methods

Rank	Method Code	Method Description
1	127	R - P Co Partisol Model 2025
2	126	R - P Co Partisol Model 2000
3	098	R&P Model 2000 Partisol
4	079	INSTRUMENTAL-R&P SA246B-INLET
5	125	BGI Inc. Model PQ200 PM10
6	124	BGI Inc. Model PQ100 PM10
7	900	BGI Inc. frmOMNI at 5 lpm
8	063	HI-VOL SA/GMW-1200
9	064	HI-VOL-SA/GMW-321-B
10	065	HI-VOL-SA/GMW-321-C
11	162	Hi Vol SSI Ecotech Model 3000
12	130	Andersen RAAS10-100 Single channel
13	131	Andersen RAAS10-200 S-Channel
14	132	Andersen RAAS10-300 M-channel
15	141	Tisch Environ Model-6070 PM10 Hi-Vol
16	062	HI-VOL-WEDDING-INLET
17	773	LO-VOL-DICHOT-INTERIM
18	073	LO-VOL-DICHOTOMOUS-SA246B-INLT
19	071	OREGON-DEQ-MED-VOL

Table 3. Ranking of O_3 collection methods

Rank	Method Code	Method Description
1	047	Ultraviolet Absorption – Thermo Electron 49
2	103	Open Path Ozone Analyser - OPSI Model AR 500 Ozone Analyzer
3	056	Ultraviolet Absorption - DASIBI 1008-AH
4	019	Ultraviolet Absorption - DASIBI 1003-AH--PC—RS
5	053	Ultraviolet Absorption - Monitor Labs 8810
6	078	Ultraviolet Absorption - Environics Series 300
7	087	Ultraviolet Absorption - Model 400 Ozone Analyzer
8	112	Ultraviolet Absorption – Horiba APOA-360
9	105	UV Photometric - Environment SA Model Q341M
10	020	Chemiluminescence - Beckman 950A
11	--	Other

Table 4. Ranking of SO_2 collection methods

Rank	Method Code	Method Description
1	560	Pulsed Fluorescence - Thermo Electron 43C-TLE
2	060	Pulsed Fluorescence - Thermo Electron 43A, 43B, 43C
3	009	Pulsed Fluorescence - Thermo Electron 43
4	--	Other

Table 5. Ranking of EC/OC collection methods

Rank	Method Code	Method Description
Chemical Speciation Network (CSN) Temperature Protocol, Total Optical Transmittance – AQS parm 88305 and 88307		
1	847	R & P Model 2025 PM2.5 Sequential Quartz VSCC
2	843	R & P Model 2025 PM2.5 Sequential Quartz
3	853	R&P MDL2300 PM2.5 Seq Spec Quartz
4	873	URG MASS450 Quartz VSCC
5	833	URG MASS450 Quartz WINS
6	823	Andersen RAAS Quartz
7	813	Met One SASS Quartz
IMPROVE Temperature Protocol, Total Optical Reflectance - AQS parm 88320 and 88321		
1	859	R & P Model 2025 PM2.5 Sequential Quartz VSCC
2	857	R & P Model 2025 PM2.5 Sequential Quartz
3	855	R&P MDL2300 PM2.5 Seq Spec Quartz
4	877	URG MASS450 Quartz VSCC
5	829	URG 3000N w/Pall Quartz filter and Cyclone Inlet
6	838	URG 3000N w/Pall Quartz filter and Cyclone Inlet
7	837	URG MASS450 Quartz WINS
8	815	Met One SASS Quartz
9	825	Andersen RAAS Quartz
10	809	IMPROVE Module C with Cyclone Inlet-Quartz Filter
11	805	IMPROVE
IMPROVE Temperature Protocol, Total Optical Transmittance		
--	838	URG 3000N w/Pall Quartz filter and Cyclone Inlet, Unadjusted – AQS parm 88355 and 88357
--	840	URG 3000N w/Pall Quartz filter and Cyclone Inlet, Unadjusted – AQS parm 88355 and 88357
Revised CSN Temperature Protocol, Total Optical Reflectance, Unadjusted		
--	831	URG 3000N w/Pall Quartz filter and Cyclone Inlet – AQS parm 88370 and 88380

Elemental and organic carbon (EC/OC) are not listed as criteria air pollutants, and as such have no federal reference methods. Similar equipment is used for the collection of samples for EC/OC analysis as is used for the collection of $PM_{2.5}$ for gravimetric analysis, so similar rankings were used to prioritize EC/OC methods. One issue that is important to consider when requesting EC/OC data is that these pollutants are operationally defined. Through 2007, EC/OC was primarily measured using the Chemical Speciation Network (CSN) temperature protocol. In 2007, many locations switched to using the IMPROVE temperature protocol. Comparisons between HEI/NPACT EC/OC measurements and monitoring network measurements by different protocols are presented in the XRF and EC/OC supplement to the QA report (available upon request).

AQS monitors collect hourly NO_X and NO_2 data by chemiluminescence, generally reported in units of ppm (and stored in the EAC database in units of ppb). All chemiluminescent methods are considered equivalent, so data for the monitor with the more complete time series were retained for days with two monitors' data available. If a duplicate monitor existed, data from that monitor were inserted into the time series for time periods during which only that monitor's data were available.

Speciated data for the same species are rarely assessed using more than one method, so data for the monitor with the more complete time series were retained for days with two monitors' data available. If a duplicate monitor existed, data from that monitor were inserted into the time series for time periods during which only that monitor's data was available.

1.2.2 AQS Locations

AQS locations were downloaded from AQS Data Mart as latitude and longitude. Flat files were converted to shapefiles in ArcGIS and re-projected into the appropriate State Plane Coordinate System before geographic variables were calculated.

AQS monitoring locations are identifiable by unique identifiers assigned by the EPA. These identifiers have three parts: a two digit state code, a three digit county code, and a four digit site code. Individual monitors at monitoring sites also have a five digit pollutant code, and a two-digit 'parameter occurrence code' (POC). The two digit state code and three digit county code are defined under the Information Technology Management Reform Act (Public Law 104-106) and the National Institute of Standards and Technology (NIST) for Federal computer systems. The four digit site code site code defines unique AQS monitor locations within certain counties, and the five digit parameter code defines the specific parameter being collected by a designated monitor. For example, a $PM_{2.5}$ monitor in Los Angeles County, California at site 0001 could be numbered 0603700018810101. As described above, multiple monitors for the same pollutant are occasionally operated concurrently at the same site. The POC identifies unique monitors in this case, with lower numbers indicating more established monitors. Maps of the AQS monitor locations for which we retain data are available online.

1.2.3 AQS Monitor Deployment Height

AQS monitors are generally deployed at ground level or on the roof of a low building, but this is not universally the case. This may be of particular importance in New York, so the floor at which monitors were deployed was obtained from the air quality agency. Monitors deployed above the ground floor in the New York City metropolitan area are flagged with this information.

1.2.4 Data completeness rules for averaging

Data completeness rules are based on a minimum number of data points and a maximum gap between consecutive measurements, which are derived from the length of the averaging period and the typical monitoring frequency of the pollutant in question.

Table 6. Data completeness rules for averaging

Averaging Period	**Maximum Gap**	**Minimum Data Points**		
		1-in-6 Days (PM_{10}, Elements, Carbon Species)	1-in-3 Days ($PM_{2.5}$)	Daily (Gases)
Two Weeks	12	2	4	10
One Month	12	4	7	21
Six Months	15	21	41	122
Nine Months	30	31	61	127
One Year	45	41	82	244

Note that ozone is measured seasonally at approximately half of locations. For many applications, it may be more appropriate to request the April – October average rather than the annual average.

These standards were established for convenience and are not expected to cover the needs of every data request. All available AQS data are housed in the EAC database, not just those meeting these criteria. Users are welcome to design their own inclusion criteria; space is provided in the electronic data request form to outline criteria specific to each user's needs. The monitor identification numbers are indicated on the study area maps at http://www.uwchscc.org/MESAAP/Data.aspx, so that users can list individual monitor numbers for which they would like data. These maps indicate the monitors that are included in the standard set, as well as additional monitors in the region. If no inclusion criteria are described, the standards above will be used as the default.

1.2.5 Quality Control

Air pollution monitoring is primarily conducted to comply with federal regulations, though individual air quality agencies may have other secondary objectives. Siting priorities, funding, local culture, and chance all have the potential to impact the quality of data from individual monitors. Therefore, certain criteria have been set for the inclusion of AQS data. After data are downloaded, the "Basic Level" of QC consists of the following steps:

- Limits of detection (LOD) are determined from the documentation available on the AQS website; some may depend on the collection or analysis method. A range is provided for these species.

Parameter	**LOD**
NO_X/NO_2	1 ppb
SO_2	2-5 ppb
O_3	1.5-5 ppb
AQS $PM_{2.5}$	2 $\mu g/m^3$
IMPROVE $PM_{2.5}$	0.0562-2 $\mu g/m^3$
speciated elements from the STN	0.0001-0.0347 $\mu g/m^3$
speciated elements from the IMPROVE network	0.00001-2.23 $\mu g/m^3$
EC/OC	0.002-0.245 $\mu g/m^3$
IMPROVE EC and OC	Not listed

- Measurements below the limit of detection (LOD) are replaced with a value equal to half the LOD. These values, and any daily averages associated with them, are assigned an 'LOD' flag.
- Very high outliers (>= 1000 ppb for gases or >=1000 $\mu g/m^3$ for $PM_{2.5}$) are investigated. Occasionally, the wrong units appear to have been assigned to the raw data (i.e. ppm instead of ppb) by the local agency. A more reasonable unit may be assigned by the data manager, but since the air quality agency typically is not asked to confirm this error, the measurement is associated with a 'unit' flag.
- Daily averages are calculated for those pollutants for which AQS captures hourly data, provided that the hourly measurements (where they exist) meet the following criteria. The same applies to daily meteorology data that is computed from hourly data:
    - At least 18 hours for the day are available
    - At least 4 hours between 4:00 am and 9:00 am are available
    - At least 4 hours between 1:00 pm and 6:00 pm are available
- For ozone, the 10 am – 6 pm average will also be available. The inclusion criterion for these measurements is that 6 of the intended 8 hours must be available.
- For ozone, the maximum 8-hour average will also be available. This measurement can be calculated only if that day's data meets the daily average criteria and if at least 6 hours' data are available for each 8-hour averaging window.

- A small amount of additional data are excluded based on personal communication with local air monitoring agencies, which is documented in the Monitor Issue Log (see Appendix C). If extremely suspicious data were brought to the attention of a local agency, but no response was received or the agency confirmed its validity, then those data are retained in the database but may be assigned an 'Agency' flag to alert the analyst.

1.2.6 Data Archiving

Older versions of the AQS data already used for publications and manuscripts have sometimes been archived on DVD, including a pre-database version of AQS data for the years 1980-1999. Historical versions of data within the EAC database are archived in compressed files that can be accessed to fill old data requests or retrieve older versions of covariates and predictions.

1.3. Monitoring Data from DEOHS Air Monitoring Studies

Below are overviews of the types of air monitoring that our working group has conducted. There are study-specific QA/QC documents and other materials that are available and can be accessed as needed. Some of these documents are listed in Appendix C. The EAC database contains the dates that sampling started and ended for each individual measurement, as well as the middle day of the intended two-week sampling period (typically a Wednesday). Samples with concentrations below the LOD are flagged, and the LODs associated with these samples are provided. Additional flags for minor circumstances were associated with a small number of measurements as described in the final Quality Assurance / Quality Control Report (see Appendix C).

In addition to the geographic covariates that are available for all locations, DEOHS monitoring locations are also associated with a building floor at which the data were collected. This is primarily of interest in cities such as New York where many living units are located well above street level. For the Coarse monitoring sites and where the living floor is not indicated, data were collected at the first (ground) or second floor.

1.3.1 Fixed Site Monitoring

Fixed sites are similar to AQS sites in that they are designed to collect a continuous series of measurements over the monitoring period. Fixed sites were operated continuously in all MESA Air regions (2-5 per region) from approximately July 2005 until July 2009. The exact start and end dates vary from site to site. The methods used for these monitoring sites collected two-week integrated measurements, using either Teflon filters for PM or Ogawas for gases. Each PM sampler was intended to run on a 50% duty cycle for consecutive two-week intervals. These sites were chosen to represent MESA Air participant exposures, near road exposures, or were co-located with an AQS monitor in the area. $PM_{2.5}$ (for mass, LAC, and elements), NO_2, NO_X, SO_2, and sometimes O_3 were measured at these sites. The HEI/NPACT study collected $PM_{2.5}$ for EC/OC analysis at these sites during some time periods.

Remote Air Data (RAD) /"Low-Cost" Sensor Monitoring: "Low-cost" sensors with 5-min resolution for $PM_{2.5}$, NO_2, NO, CO and O_3 were deployed in the seven regions of the ACT AP and MESA Air studies (Seattle, WA; Los Angeles, CA; St. Paul, MN; New York City, NY; Chicago, IL; Winston-Salem, NC; Baltimore, MD). In Seattle, monitors were deployed at participant and volunteer homes, community sites and co-located at AQS sites, from Spring 2017 through Winter 2019, with a few locations in operation until summer 2021. Other regions had slightly shorter deployment periods and less monitors, which were primarily sent to AQS sites (except Baltimore which also had 2 periods of home site monitoring). Sensors were calibrated using regression models developed with co-located government

monitoring data. Quality Control screens were done to remove clearly broken sensor data. Calibrated data is available for $PM_{2.5}$ in all regions, CO in Seattle and Baltimore, and $NO_2/NO/O_3$ in Seattle only. However, data quality is a concern for some of the data, especially the gas sensors which had several issues making calibration difficult ($NO_2/NO/O_3$ in particular).

1.3.2 Home Outdoor Monitoring

Home outdoor monitoring refers to air monitoring conducted outside residential locations, primarily of participants involved in one of the health studies. In theory, repeated monitoring periods (or rounds) at the same home were intended to occur in distinct seasons: summer, winter, or "transitional" (spring or fall). Home outdoor monitoring was conducted in MESA Air, SPIROMICS Air, ACT-AP, CCAR Project 5 (Ogawas and VOCs), and the PM Center Panel Study.

1.3.3 Home Indoor Monitoring

Home indoor monitoring occurred at a subset of outdoor home monitoring locations. Similar sampling set-ups were operated concurrently inside and outside the participant's home. $PM_{2.5}$ (for mass, LAC, and elements), NO_2, NO_X, SO_2, and O_3 were measured at these sites in MESA Air. SPIROMICS Air additionally included nicotine. CCAR Project 5 included VOCs but not $PM_{2.5}$.

1.3.4 Personal Monitoring

Personal monitoring occurred at a subset of indoor home monitoring locations. Participants carried samplers for NO_X, NO_2, SO_2, and $PM_{2.5}$ (for mass, LAC, and elements) for two weeks in MESA Air. In SPIROMICS Air, participants carried NO_X, NO_2, SO_2, and O_3 samplers for two weeks. CCAR Project 5 participants carried these Ogawas as well as VOC samplers.

1.3.5 In-Vehicle Monitoring

In-vehicle monitoring occurred in the personal vehicles of subjects that participated in CCAR Project 5. These NO_X, NO_2, SO_2, O_3, and VOC samplers were sealed in canisters when then vehicle was not in use.

1.3.6 Roadway Gradient Snapshot Monitoring

Snapshot monitoring included ~100-150 individual locations monitored simultaneously for a two-week period using Ogawas on telephone poles. The aim of this type of campaign is to learn more about pollutant gradient near roads. Gradient-type snapshot monitoring was conducted by MESA Air, SPIROMICS Air, and ACT-AP.

1.3.7 Other Kinds of Snapshot Monitoring

MESA Air Coarse PM: The Coarse PM Study collected snapshot data in the winter and summer at MESA Air participant homes in Chicago, Winston-Salem, and St. Paul. This study measured $PM_{2.5}$, PM_{10}, and endotoxin, and was conducted primarily at participant homes. $NO_X/NO_2/SO_2$ Ogawa data from these home locations is available for most sampling rounds.

CCAR "Fuzzy Points": The Center for Clean Air Research Project 1 conducted mobile monitoring campaigns in Atlanta, Winston-Salem, St. Paul, LA, and Baltimore. "Fuzzy points" were intersections that the monitoring vehicle passed through several times from different directions. Ogawa and VOC badges were hung near these intersections over the 2-week monitoring periods. Each city was sampled in a heating (winter) and non-heating (summer) season.

LAX "Flightpath": Two airplanes land at LAX every minute between 6:30 am until midnight, with all airplanes following the same flightpath over Inglewood. During Fall 2014, 24 NO_X/NO_2 Ogawas were distributed in roughly a grid pattern in this community.

Yesler Terrace: The Seattle Housing Authority was planning a re-development of the Yesler Terrace neighborhood. NO_X/NO_2 Ogawas were deployed at 28 locations in February 2010 and 86 locations in March 2010.

Diesel Exhaust Exposure in the Duwamish Study (DEEDS): DEEDS measured $PM_{2.5}$, light absorbing carbon (indicated by filters' light absorption coefficients), NO_X, NO_2, and SO_2 at snapshot sites in Seattle, WA in Summer and Winter 2012. These data are described in Jill Schulte's DEOHS master's thesis. All monitoring results are based on a two-week integrated sampling design.

Table 7. Pollutant availability by study. Rounds per home refers to home outdoor monitoring. Rounds per pole refers to snapshot monitoring. The air monitoring methods were either two-week integrated (TWI) using HPEMs and passive badges or remote air data (RAD).

Study	Geographic Area	Time Period	Rounds per Home	Rounds per Pole	$PM_{2.5}$	NO_X	NO_2	O_3	Other
Yesler Terrace	Seattle	2010		2		TWI	TWI		
DEEDS	Seattle	2012		2	TWI	TWI	TWI		1-NP
MESA Air	MESA Air cities[1]	2005 – 2009	1-3	3	TWI	TWI	TWI	TWI	XRF
MESA Air – Coarse	Winston-Salem, St. Paul, Chicago	2009	1-2		TWI	TWI	TWI	TWI	Endotoxin, PM_{10}
CCAR Project 1	LA, Baltimore, Winston-Salem, St. Paul, Atlanta	2011-2013		1-2		TWI	TWI	TWI	VOCs (TWI)
CCAR Project 5	LA, Winston-Salem	2013-2014	1-2			TWI	TWI	TWI	VOCs (TWI)
CCAR Flightpath	LA	2014		1		TWI	TWI		
SPIROMICS Air	SPIROMICS cities[2]	2014-2016	1-2	1-2	TWI	TWI	TWI	TWI	Nicotine (TWI)
ACT – Air Pollution	Seattle	2017-2019	2	3	RAD	Both	Both	Both	CO (RAD)
MESA air R56	Baltimore	2017-2018	1-2		RAD	RAD	RAD	RAD	CO (RAD)
PM Center Panel Study	Seattle	1999-2002	1-2		TWI/Neph	TWI	TWI		

[1] MESA Air Cities: Winston-Salem, NC; New York City, NY; Baltimore, MD; Chicago, IL; St. Paul, MN; Los Angeles, CA

[2] SPIROMICS Air Cities: Winston-Salem, NC; New York City, NY; Baltimore, MD; Los Angeles, CA; Ann Arbor, MI; Salt Lake City, UT; San Francisco, CA

1.3.8 Data Description

Sampling designs prior to 2017 were generally intended to yield consecutive two-week integrated air pollutant measurements. The start and end dates of each sampling event are available, and the 'intended middle day' is available for MESA Air measurements. Pump failure, building closures, and participant availability often resulted in measurements that were shorter than two weeks or that were shifted from the standard Wednesday-to-Wednesday schedule by one or two days. A few Coarse PM Study snapshots were scheduled for a two week period that began and ended on a day other than Wednesday. For all MESA Air samples, the 'intended middle day' is the Wednesday that best aligns that sample with the standard Wednesday-to-Wednesday schedule in that study area. For the Coarse PM Study snapshots, the intended middle day aligns all of the Coarse PM samples that were collected concurrently. SPIROMICS Air homes were deployed over the course of 1-2 weeks and do not have an intended middle day.

Measurements are reported as ppb for gases. Gas samples collected via Ogawas are analyzed using ion chromatography (IC) analysis, which is quite sensitive and can detect very small concentrations of ions. However, a small number of measurements were made that were below the detection limit of the instrument, also known as the lab LOD. These measurements will be reported as half the noise in the instrument's baseline.

Samples typically accumulate a small amount of contamination during handling and shipping. This level will often exceed the lab limit of detection. "Field blanks" are used to determine this level of contamination, and are used to determine a correction for contamination and the "field" limit of detection. The limit of detection is provided along with the measured value (after correction), as some users may choose to replace the measurements made below the LOD with other values. More information about correction and limits of detection can be found in the QA/QC report (see Appendix C).

Measurements are reported as $\mu g/m^3$ for particulate matter. Because particulate matter mass is determined gravimetrically for the two-week integrated method, and because the microbalance can always provide a filter's weight, lab LODs are not available. Other measures of uncertainty are addressed in the QA/QC report. The field LOD is determined for mass for PM, EC/OC, and elemental species. Data users will receive this LOD as a concentration, calculated by the volume of air sampled. Because the volume of air varies by sample based on sampling duration and flow rate, the concentration LOD will not be the same for all samples. As for gases, data users will receive both the corrected measurement and the LOD. RAD monitors evaluate particulate matter using a laser (Plantower).

1.3.9 Quality Control of Data

A full treatment of the QA/QC process for all of our monitoring data is out of scope for this document. Please refer to a project-specific Quality Assurance Project Plan (QAPP) and the final Quality Assurance/ Quality Control Report (see Appendix C) as needed.

Flags are associated with a small number of measurements and are provided to data users. Measurements taken near a source of pollution or with concentrations that might be impacted by slight deviations from the sampling protocol are indicated with a Source or Concentration flag. A full description of the flags exists in the QAPP and the final QA/QC report (see Appendix C). There are also a

number of measurements that were noted as unbelievable by analysts that have worked extensively with these data. These flags are provided with a brief description of the issue that the analyst identified.

1.3.10 Raw Monitoring Data

Raw data include field log data, questionnaire data, and measurements. The collection, measurement, and transmittance of samples and data are covered extensively in the relevant field and lab Standard Operating Procedures documents (see Appendix C). Locations of the raw monitoring data files are listed in this Appendix.

1.4 Monitoring Data from Other Sources

1.4.1 Inhalable Particulate Network (IPN)

The Inhalable Particulate Network (IPN) was an EPA monitoring campaign from 1979 to 1984. This network included fine particulate measurements ($PM_{2.5}$) and coarse particulate measurements ($PM_{2.5}$-PM_{15}) taken from dichot samplers, "inhalable particulates" (PM_{15}) taken from size-selective input HIVOL samplers, and "total suspended particulate matter" (PM_{30}) taken from HIVOL samplers, as well as a variety of other particulate components.

The EPA no longer has any data associated with this network. We digitized a printout of the data that was transferred to us from colleagues at NYU. Note that while this dataset was printed in 1984, measurements only extend through 1982 (indicating the printed version we have was not the final dataset). This printout contained site codes but not site locations. We manually linked site codes to tables with geographic locations; these tables were found in two separate EPA documents (Analysis of Inhalable and Fine Particulate Matter Measurements 1981 and Directory of Air Quality Monitoring Sites Active in 1977). Out of the 132 sites with fine PM ($PM_{2.5}$) measurements, 102 of these sites were listed in either of the documents containing geolocations, and therefore 30 sites are missing lat/long data and geocovariates. Data from these 30 sites are therefore unusable.

Table 8. Description of particle pollution data available from IPN, including particle size and collection methods.

Pollutant	Equipment	Description	Particle size range (µm)
PM30	11 ½" x 15 " hi volume sampler (HIVOL)	Total suspended particulate matter (TSP) is the portion of suspended material collected by the HIVOL filter sampler for a 24hr period; 50% cut size from 30 to 65 µm for wind speeds between 2 to 24 km/hr	0 – 30
PM15	11 ½" x 15 " hi volume sampler (HIVOL) equipped with 15 µm size-selective inlet (SSI) and flow controller	USEPA "inhalable" particulate matter (IP); that portion collected by a sampler with a 50% cut size of 15 µm	0 – 15
PM25	Sierra 244, 244e or Beckman SAMPLAIR virtual impactor (aka dichotomous sampler)	Fine particulate matter; that portion of an aerosol which penetrates a particle collector with a 50% cut size at 2.5um	0 – 2.5
PMcf	Sierra 244, 244e or Beckman SAMPLAIR virtual impactor (aka dichotomous sampler)	Course particulate matter; presumably everything from the dichot not included in mass_f	2.5 – 15

1.4.2 New York City Community Air Survey (NYCCAS)

NYCCAS collected 2-week measurements of air pollutants ($PM_{2.5}$, LAC, NO_X, O_3) at utility pole locations throughout the 5 boroughs beginning in December 2008. Our database currently contains measurements collected through November 2019. More information regarding site selection can be found on NYCCAS' website:
http://www.nyc.gov/html/doh/html/environmental/community-air-survey.shtml

1.5 Participant Address History

1.5.1 MESA Air and MESA Neighborhood Participants

The main MESA study collected current addresses on all MESA Classic participants from the baseline exam and updated these addresses at all subsequent follow up calls and clinic visits. At the beginning of MESA, addresses were only used for mailings, etc. and out-of-date addresses were overwritten by current addresses. In Exams 2 and 3, the MESA Neighborhood study, a study ancillary to MESA and directed by Dr. Ana Diez Roux at the University of Michigan, administered a Residential History Questionnaire to all MESA Classic participants who attended these exams and consented to MESA Neighborhood. This questionnaire acquired historical addresses from 1980 until the administration of the survey. MESA Air funded identical Residential History Questionnaires on all MESA Air New Recruits and MESA Air participants recruited from the MESA Family study during Exams 3/4. In 2006, MESA Air

requested that all addresses collected by the main MESA study during clinic visits and follow up phone calls be retained by the Coordinating Center. Residential histories are available participants in the MESA Neighborhood Study for the period between 1980 and Exams 2/3 (2002-2004), and from the main MESA study from 2006 onward. Address histories were also verified or corrected according to a residential history interview conducted during Follow-Up 14. Living floor and building type are available for locations for which an Air Questionnaire was administered.

The MESA Neighborhood study cleaned all addresses they collected, and contracted with Mapping Analytics to geocode the cleaned addresses. In geocoding these addresses, Mapping Analytics employed a 50 foot offset from the centerline of the road. The EAC database includes the geocodes generated by Mapping Analytics for the addresses at which participants lived between 1980 and 1999, with a few exceptions as described below. The MESA Air EAC geocoded all addresses where participants reported residing from January 1, 1999 forward with ArcGIS using a 30 foot offset perpendicular to the street. During data cleaning, MESA Air recovered some addresses that Mapping Analytics was not able to geocode. These were geocoded with a 30 foot offset.

Efforts were made to establish an address history that was sensible and complete, such that each participant had a single residence for every time point between 1980 and 2010. In the residential history, not all addresses had move-in or move-out dates. Addresses were ordered by available move dates and track date (contact date or date of questionnaire administration). A missing move-in date was assigned as the day after the previous addresses' move-out date. A missing move-out date was assigned the day before the track date of the next address, unless the last-known date at the previous address was also a track date. If only consecutive track dates were available, then the midpoint of the dates was used as the move-out date and the next day was used as the move-in date. Some track dates were misclassified as move-in dates; these were identified by comparison to available exam dates and track dates. PO Box addresses were dropped whenever possible, though included (and flagged) if no other address appeared to be valid for the concurrent time period. If only month and year (not day) were available for move dates, the move-out date was assigned to the end of the month, and the move-in date was assigned to the beginning of the month. If the year was available for the move date, but not the month or day, the middle date of the year was used. If two addresses had the same track dates, the midpoint of the difference was used for the move dates. The majority of these rules were based on those employed by the MESA Neighborhood study at the University of Michigan.

Decease dates were provided by the Coordinating Center. For these participants, an end date for the last known address was set as the decease date. Last known addresses for other participants have an end date in the far future.

The majority of addresses included in the database are the participants' primary addresses, but some participants also provide secondary addresses, which are indicated as appropriate.

1.5.2 Technical Note: Address geocoding and geocode flags

We use ArcGIS for all geocoding, but the version of ArcGIS and the underlying maps have changed over time, so locations added to the database more recently use a more recent ArcGIS version and more recent base map than locations added previously. Prior to Rev 12 (released in July 2019), participants' home addresses (street address, city, state, and zip code) for MESA were geocoded in ArcGIS 9.2 or 9.3 (ESRI, Redlands, CA) using data provided by the MESA Coordinating Center and the TeleAtlas Dynamap 2000 v.16.1 road network (Boston, MA). Participant addresses that were added in Rev 12 (YYYY) were

geocoded using ArcGIS 10.5.1, Business Analyst, and the USA Local Composite 2016 parcel and street information. More recent addresses were geocoded using the contemporary version of ArcGIS and the USA Local Composite 2018.

Previously

MESA Air participant locations are geocoded at the EAC using automated geocoding procedures in ArcGIS for all addresses that match up to a selected sensitivity (80% for this study). Spelling sensitivity and minimum match score are both set to 80 for automated geocoding. The default minimum candidate score, 10, is used. Originally, the "side offset"[1] used was 30 feet, with a 0 foot end offset (the default in ArcGIS 9.2 and 9.3). Addresses that were geocoded onto A1, A2, or A3 roads due to the 0 offset setting were re-geocoded with a 3 percent end offset (the default in ArcGIS 10). In the event that ArcGIS is unable to match the address with 80% accuracy, it will prompt the user to match the addresses interactively. The user must exercise good judgment for this process, and common fixes include removing apartment or unit numbers, fixing spelling errors, and checking the address with Google Earth, Google Maps, or Bing Maps.

More recent addresses were geocoded with the parcel-based geocoding available starting in ArcGIS10. We also re-geocoded a subset of addresses located very close to roadways, since very small differences in locations near roads can have a large influence on exposures. Ideally, all locations would be geocoded using parcel-based geocoding, but it would be time-consuming to create new geocodes (and, more importantly, new geocovariates) for all locations, and the differences in locations between street- and parcel-based geocodes are generally small and likely only important for locations near roads. In addition, the data underlying parcel-based geocoding is not available for all locations, so at best, parcel-based geocoding could only happen in a subset of homes. To select the locations to re-geocode and relocate using the parcel data, we selected all locations identified as being with 150 m of a major road based on the street geocodes and, when possible, calculated the parcel geocodes. If the parcel geocode and street geocodes were more than 100m apart or more than 50% different, and the parcel geocode was more than 10 m from any major road, the parcel geocode replaced the original geocode. A street geocode was retained if the parcel geocode fell within 10 m of a road.

All addresses geocoded to the exact location by street geocoding will be noted as "Exact" under the geocode type; those geocoded to an exact location by parcel geocoding will be noted as "Parcel". Occasionally a road may have more than one name, so any addresses that were geocoded with different street names to exactly the same location were considered exact matches. Some addresses were identifiable through Google Earth but could not be geocoded to the exact street number in ArcGIS. These addresses were geocoded to the nearest intersection on the same street. For invalid street addresses with a valid zip code, participant locations were geocoded to the centroid of the zip code. Intersection and zip code geocodes were always created via street (not parcel) geocoding methods. Invalid addresses, such as addresses with no valid zip code, PO Boxes, and addresses outside the continental US, were noted as fatal. Each address will be associated with one of the geocode types that are listed below.

[1] Roads are provided as line features by TeleAtlas, and as such have no width. The position of the line is considered to be the centerline of the road. The "side offset" is the number of meters away from the centerline that the address is presumed to lie in the perpendicular direction. Road shapefiles contain information as to which side of the street has even or odd street addresses, so that points are placed on the correct side of the street.

Table 9. Geocode types

Geocode Level of Precision	Geocoding Agent	Geocode Type
Address was not found (fatal)	EAC or Mapping Analytics	FATAL
Address was a PO Box (fatal)	EAC or Mapping Analytics	POBOX
Address is outside the continental US (fatal)	EAC or Mapping Analytics	FOREIGN
Outside the larger MESA Air Area	EAC or Mapping Analytics	OUT OF AREA
Exact match, 30 foot offset, 80% match rate	EAC	EAC-EXACT
Exact match to parcel data, no offset	EAC	EAC-PARCEL
Centroid of zip code	EAC	EAC-ZIP
Nearest intersection, 30 foot offset	EAC	EAC-INTERSECTION
Exact match, 50 foot offset, 100% match rate	Mapping Analytics	MICH-EXACT
Nearest intersection, 50 foot offset	Mapping Analytics	MICH-INTERSECTION
Centroid of block group	Mapping Analytics	MICH-BLOCK
Centroid of census tract	Mapping Analytics	MICH-TRACT
Centroid of zip code	Mapping Analytics	MICH-ZIP
Centroid of county	Mapping Analytics	MICH-COUNTY

1.5.3 Cardiovascular Health Study (CHS) Participants

For Rev 14, CHS address locations and address histories were replaced with a new dataset providided by the CHS Coordinating Center. Geocoding for Rev 14 was conducted using Business Analyst for ArcGIS 10.3.

1.5.4 Women's Health Initiative – Observational Study (WHI - OS) and Clinical Trial (WHI – CT) Participants

Addresses for participants in the Women's Health Initiative were collected and geocoded by the WHI Coordinating Center. These addresses were collected at the participants' initial interview and at follow-up. Follow-up after 2009 was conducted primarily by mail. As of Rev 14, address locations through 2016 were included in the database. The latitudes and longitudes of these locations were transmitted to the EAC without street addresses, participant names, or participant unique numbers, and with 20% of the locations being "QC" locations rather than participant residences. The exact method of geocoding for these addresses is not known, and no data cleaning was performed by the EAC.

1.5.5 SPIROMICS Air Participants

Addresses were provided by the Coordinating Center at UNC with a dummy participant ID and were geocoded at the EAC. Participants were asked to provide the current address at baseline as well as all addresses at which they had lived for 10 years prior to the study. The current address and any recent addresses were recorded at follow-up visits and during quarterly follow-up calls. Geocoding for Rev 11 was conducted using Business Analyst for ArcGIS 10.3, with no offset.

1.5.6 ACT – Air Pollution Study

Billing and study addresses (from ACT records, a LexisNexis search for deceased and cognitively impaired former participants, and a residential survey for a small number of participants) were provided by Kaiser Permanente Research Institute (KPRI) with a dummy participant ID and were geocoded at the EAC. Geocoding for Rev 14 was conducted using Business Analyst for ArcGIS 10.3.

1.5.7 The Sister Study and the Two Sister Study Participants

Addresses for participants in The Sister Study and the Two Sister Study were geocoded at the EAC in two batches. The first batch included four kinds of addresses: "current" (at enrollment), secondary (at enrollment), longest-lived, and childhood (indicated in that order by a string of 4 binary digits at the end of the native_id). Participants were enrolled between 2003 and 2009. The same types of addresses were geocoded for the Two Sister Study. Participants in The Sister Study were women whose sisters had breast cancer; the Two Sister Study was an ancillary study to The Sister Study that enrolled the women with breast cancer themselves (the sisters of The Sister Study original participants.) Participants in the Two Sister Study were enrolled between 2008 and 2010. Geocode types are similar to the EAC types that are listed in Table 6: exact, intersection, zip, or fatal.

The second batch of addresses included addresses, contact dates, and move dates since enrollment for Sister Study participants only (i.e., not Two Sister Study). The EAC determined a unique address history for each Sisters participant and then conducted geocoding using Business Analyst for ArcGIS 10.3.

1.5.8 REGARDS Study Participants

Te REGARDS Coordindating Center provided the EAC with geocodes for REGARDS participants from baseline up through Dec 19, 2017. All data cleaning and geocoding were conducted by the REGARDS Coordinating Center, which used SAS to geocode locations. Start dates were set to 2 years prior to enrollment.

1.5.9 Small-Fee Projects

Collaborators sometimes send us a small set of locations for which they would like model predictions and sometimes geographic covariates. Users will know what to request if they need this kind of data.

1.6. Participant Exam Dates

The dates on which each MESA or MESA Air participant came into the clinic for each of the five MESA exams are provided to the EAC by the Coordinating Center. In addition to the primary exam date, the Coordinating Center also provided the dates for each participant's coronary artery CT scan, ultrasound, spirometry, and MRI as these tests sometimes occurred on a separate day.

Since a very limited number of participants have an exam at a given field center on any particular day, these dates are considered identifying information and, as such, cannot be distributed by the EAC. These dates are used by the EAC to provide "year prior to exam" averaging or time boundaries. Thus, in some cases, address histories and exam dates may be 'masked' by providing a move date or exam date as the number of days since an event of interest (such as a participant's baseline exam).

In addition, exam dates for SPIROMICS Air participants are available.

1.7. Participant Time Location

As part of the MESA Air Questionnaire, participants reported location patterns by season (summer or winter) and day of the week. This included questions specific to the number of hours spent in transit, at home indoors and out, at work indoors and out, and at "other activity locations" (such as volunteering) indoors and out. The primary purpose of these data is to provide time-weighted, infiltration-adjusted, aggregated estimates of $PM_{2.5}$ exposure, or to provide the percent of time spent indoors and outdoors. For these calculations, we sum the total time spent in indoor locations (reported as home indoor, work indoor, and other indoor) and outdoor locations (reported as home outdoor, work outdoor, and other

outdoor) for each season-day. We then average time indoors/outdoors across all days of the week separately for the summer and winter. When calculating individual-level exposures integrating indoor and outdoor concentrations with time-location information, the "summer" answers will be used when the two-week average temperature exceeds 18 degrees Celsius, and the "winter" answers will be used for periods with average temperatures equal to or below 18 degrees Celsius. A number of participants did not complete the Air Questionnaire, and we imputed missing responses for these participants. In instances where a participant completed some, but not all, of the time-location section of the questionnaire, we assumed that a missing day was the same as a weekday or weekend day in the same season. Otherwise, it was assumed to be the average of non-missing days. If an entire season was missing, we used the responses from the other, non-missing season. For more specific analyses involving time-location, the raw, unaggregated data are available from the Coordinating Center.

1.7.1 Pre-Adjusted $PM_{2.5}$ Exposure

Some users may prefer to conduct an analysis using $PM_{2.5}$ that has been pre-adjusted for seasonal variability, to ensure that observed effects are $PM_{2.5}$-related rather than (say) temperature-related. This would primarily be of concern when studying acute outcomes that vary seasonally, and is primarily directed at outcomes which may be 'triggered' by unusually high deviations of $PM_{2.5}$ from recent and typical levels. Pre-adjusted $PM_{2.5}$ exposures are the residuals from a prediction model of $PM_{2.5}$ that includes 6 degree of freedom per year b-splines on temperature and humidity, and 12 degrees of freedom per year on calendar time, and with categorical adjustment for day of week. The R code for pre-adjustment can be made available for analysts desiring a different model specification.

1.8. Grid Locations

The grid generation and request method is currently being dramatically overhauled. A 10 km grid covering the continental US is now the standard large scale grid. Users requesting grids should anticipate being able to request a grid by providind the upper left and lower right corner of the target area with the preferred resolution (10 m, 100 m, 500 m, 1 km, or 10 km), and request less than 100,000 locations.

1.9. Geographic Covariates

The following table summarizes the geographic variables that are available and the sources of the data. Subsections follow that address each data source in more depth. Geographic covariates are typically not available outside the continental US.

Table 10. Available geographic information

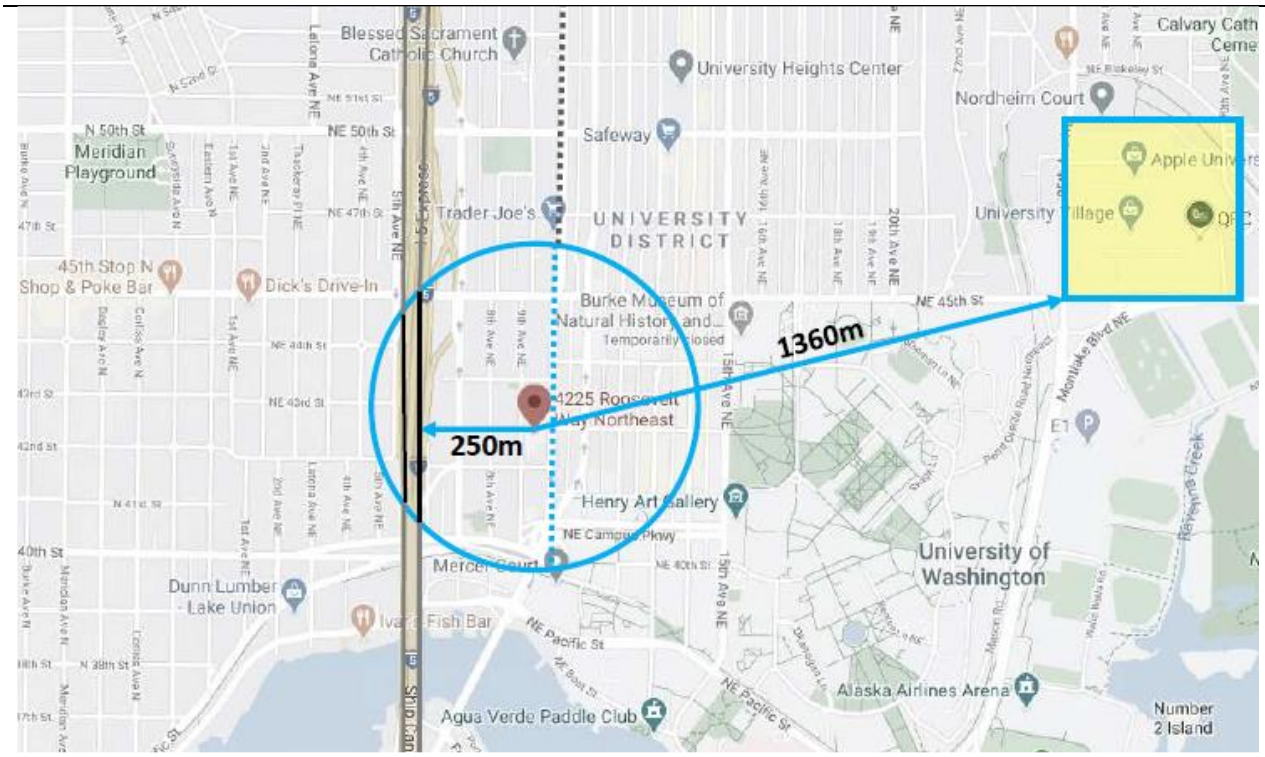
Data Category	Source	Variable Name	Available Buffer Sizes
Airports [a]	NEI Database	m_to_airp, m_to_l_airp (large airport)	N/A
Coastline [a]	TeleAtlas	m_to_coast	N/A
Railroads [a]	TeleAtlas	m_to_rr	N/A
Railyards [a]	TeleAtlas	m_to_ry	N/A
City Hall [c,d]	Google Maps	m_to_main_cityhall, m_to_local_cityhall	N/A
Roads	TeleAtlas	ll_a<type>_s<radius>	50m, 100m, 150m, 300m, 400m, 500m, 750m, 1km, 1.5km, 3km, 5km
		m_to_a1 [a], m_to_a2 [a] m_to_a3 [a]	N/A
Intersections	TeleAtlas	intersect_<type>_s<radius>	500m, 1km, 3km
		m_to_<type>_intersect [a]	N/A
Population (US)	US Census Bureau	pop_s <radius>	500m, 1km, 2km, 2.5km, 3km, 5km, 10km, 15km
Land use/ Commercial Land Use	MRLC 2006 National Landcover Dataset	rlu_<type>_p<radius>	50m, 100m, 150m, 300m, 400m, 500m, 750m, 1km, 1.5km [g], 3km, 5km, 10km [g], 15km [g]
	USGS historical source	lu_<type>_p<radius>	
		m_to_comm [a]	N/A
Ports [a]	National Geospatial Intelligence Agency	m_to_l_port, m_to_m_port, m_to_s_port	N/A
Emission Sources	NEI Database	em_<poll>_s<radius>	3km, 15km, 30km
Truck routes [a]	Bureau of Transportation Statistics	tl_s<radius>	50m, 100m, 150m, 300m, 400m, 500m, 750m, 1km, 1.5km, 3km, 5km, 10km, 15km
		m_to_truck	N/A
Impervious Surface	National Landcover Dataset	impervious_a<radius>	50m, 100m, 150m, 300m, 400m, 500m, 750m, 1km, 3km, 5km
Census Data	US Census	see **Error! Reference source not found.**	block, block group, and tract level

Table 10, continued

CALINE Long-Term Average [d]	Internal [i]	calinemod_lt_a<radius>, caline_alternate_a<radius> [h]	1.5km, 3km, 6km, 9km
Residual oil [c,e]	Environmental Defense Fund	m_to_oil, m_to_6oil	N/A
		oil_edf<oil grade>_s<radius>	100m, 150m, 300m, 500m, 750m, 1.5km, 3km
Bus routes [a,e]	NY Department of Transportation	bus_s<radius>	50m, 100m, 150m, 300m, 400m, 500m, 750m, 1km, 1.5km, 3km, 5km
		m_to_bus	N/A
Elevation [f]	National Elevation Dataset	elevation, elev_<radius>_<type>	1km, 5km
Urban Topography [j]	NYC PLUTO and City of Chicago building footprints	canyon_<type>	N/A
NDVI	University of Maryland	ndvi_<type>_a<radius>	250m, 500m, 1km, 2.5km, 5km, 7.5km, 10km
Columnar NO2	UMN	satellite_NO2	N/A
Columnar NO2	UMN	no2_behr_<yyyy>	Moore neighborhood
Satellite CO		satco_<yyyy>	Years 2000-2016
Satellite $PM_{2.5}$		satpm25_<yyyy>	Years 1998-2014
Satellite NO_2		satno2_<yyyy> satno2_<yyyy1>_<yyyy2>	Years 2005-2016
Satellite SO_2		satso2_<yyyy>	Years 2005-2016
Satellite HCHO		sathcho_2005_2016	
MOVES emissions	Internal		N/A

[a] Distances calculated to spatial features are truncated at 25 km
[c] Distances calculated to spatial features are truncated- see covariate-specific section
[d] Available only in MESA Air areas
[e] Available only for New York City
[f] Not buffered in the same way that other variables were
[j] Available for NYC and Chicago
[g] Available for USGS historical source only
[h] Available only for LA/Riverside
[i] See the "Documentation of MESA Air Implementation of CALINE3QHR Model" for details on the inputs to the CALINE dispersion model

Figure 1. Major roads may be represented by 2-4 parallel lines, such as the A1 (I-5). Here, the black lines that represent the A1 and the blue dotted line that represents an A3 are inside a 300m buffer. These lengths are summed for line length-type variables. Distances are calculated from the point (often the center of a building) to the nearest point on a line or polygon feature (such as the commercial district shaded in yellow). Example calculations: ll_a1_r00300 = 650; ll_a3_r00300 = 550; m_to_a1 = 250; m_to_a3 = 40; m_to_comm = 1360.



1.9.1 Sources of GIS data

Aside from MESA Air monitoring and home locations, geographic data are obtained from various external sources, such as TeleAtlas, the US Census Bureau, and US geological survey. All of these data are free of charge and can be acquired at any time, with the exception of the TeleAtlas data. The TeleAtlas database was obtained from the USEPA under their usage license via DVD. This DVD is currently stored at the EAC; contact the data manager if necessary. A table of other sources and their websites where data can be downloaded are listed below by data category. For detailed publication sources, publication dates and accuracy information of obtained data, please contact the EAC for the metadata document.

Table 11. Data sources

Source	URL/Contact
NEI Database	http://www.epa.gov/ttn/chief/net/2002inventory.html
TeleAtlas	http://www.teleatlas.com/OurProducts/MapData/Dynamap/index.htm
US Census Bureau	http://arcdata.esri.com/data/tiger2000/tiger_download.cfm https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml
US Geological Survey	http://water.usgs.gov/GIS/dsdl/ds240/index.html
National Geospatial Intelligence Agency	World Port Index (Pub 150) http://164.214.12.45/MSISiteContent/StaticFiles/NAV_PUBS/WPI/WPI_Shapefile.zip
EPA AQS	http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm
IMPROVE	http://views.cira.colostate.edu/web/
NDVI	http://glcf.umd.edu/data/ndvi/
National Landcover	http://www.mrlc.gov/index.php

Bureau of Transportation Statistics	http://www.bts.gov/publications/national_transportation_atlas_database/
NYC PLUTO 2004	http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml
Chicago Building Footprints	https://data.cityofchicago.org/Buildings/Building-Footprints/w2v3-isjw
National Elevation Dataset	http://nationalmap.gov/elevation.html
Environmental Defense Fund	Contact EDF attorney Isabelle Silverman
UMN Columnar NO2 (census block centroids)	Contact Julian Marshall[2]
Satellite PM2.5	http://fizz.phys.dal.ca/~atmos/martin/?page_id=140
Satellite NO2	http://www.temis.nl/airpollution/no2.html
Satellite SO2	https://disc.gsfc.nasa.gov/datacollection/OMSO2_CPR_003.html
Satellite HCHO	https://disc.gsfc.nasa.gov/datasets/OMHCHO_V003/summary
Satellite CO	https://eosweb.larc.nasa.gov/datapool

1.9.2 Creation or Projection of Shapefiles from Raw Data Sources

All geographic variables must be calculated from shapefiles. Emissions data are downloaded as flat files and shapefiles are created from latitude and longitude at the EAC. USGS land use, TeleAtlas road data, census data for the year 2000, and NDVI images are downloaded as shapefiles from the source website. All shapefiles were re-projected into State Plane Zones and clipped with a 25 kilometer 'buffer' that extends beyond the boundaries of the State Plane Zone. This enables geographic calculations for points near the border of a particular zone.

1.9.3 Land use data

Variables for land use as percentage of a buffer were calculated from two sources. USGS polygon layers, generated by manually-intensive methods using aerial photography from the 1970s and 1980s were used to calculate the variables with the "lu" prefix. Rasters based on satellite data from the year 2006 were obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium, and these were used to calculate the variables with the "rlu" prefix. In general, the EAC is recommending that the Raster Land Use data be used for exposure models developed to reflect "current" exposures (e.g., from 1999 to the present) and the USGS data be used to calculate "historical" exposure (prior to 1999). Please note that is not advisable to create an exposure model that includes both sets of land use variables. Please contact the EAC with further questions on which set of land use variables to use.

Tables 9 and 10 contain the full lists of the possible land use designations, with rough equivalents between the two sources. More information about the USGS land use classifications can be found at http://landcover.usgs.gov/pdf/anderson.pdf. The stated positional accuracy for USGS land cover is approximately 200 meters. This affects all areas, and may produce unexpected results, especially within small buffers. Analysts are encouraged to scrutinize results related to these variables. The positional accuracy for the satellite-based rasters is 30 meters and these variables may be more reliable than those calculated from the USGS polygon files. More information about the satellite- based land use classifications can be found here: http://www.mrlc.gov/nlcd06_leg.php. However, analysts are

[2] Novotny EV, MJ Bechle, DB Millet, and JD Marshall. 2011. "National satellite-based land-use regression: NO_2 in the United States". Environmental Science & Technology. 45 (10): 4407-14.

cautioned that the ice and snow designations in this data source may potentially be inaccurate, as pavement is occasionally misclassified as this land use type.

As an additional note on the processing of the polygon files, the USGS organizes land cover data by grids. Multiple grids might be required for a single State Plane Zone. Land use grids are merged into a single shapefile and projected accordingly. Commercial land use is selected and exported as a separate data category for the distance to commercial land use calculation.

Table 12. Land use variable names (lu_<type>_p<radius>) for variables based on 1970s and 1980s aerial photography

Variable Description	Variable Name (<type>)	Raster Land Use Equivalent
Urban or Built-Up Land		
Residential	resi	dev_lo, dev_med
Commercial and services	comm	dev_hi
Industrial	industrial	dev_hi
Transportation, communications, and utilities	transport	dev_hi
Industrial and commercial complexes	industcomm	dev_hi
Other urban or built-up land	oth_urban	No specific variable[b]
Mixed urban or built-up land	mix_urban	No specific variable[b]
Agricultural Land		
Cropland and pasture	crop	Crop
Orchards, groves, vineyards, nurseries	grove	Crop
Confined feeding operations	feeding	Crop
Other agricultural	oth_agri	Crop
Rangeland		
Herbaceous rangeland	herb_range	Grass
Shrub and brush rangeland	shrub	Shrub
Mixed rangeland	mix_range	Shrub
Forest Land		
Deciduous forest land	forest	decid_forest
Evergreen forest land	green	evergreen
Mixed forest	mix_forest	mix_forest
Variable Description	**Variable Name (<type>)**	**Raster Land Use Equivalent**
Water		
Streams and canals	stream	water
Lakes	lakes	water
Reservoirs	reservoir	water
Bays and estuaries	bays	water
Wetland		
Nonforested wetland	nf_wetland	herb_wetland
Wetland	wetland	woody_wetland
Barren Land		
Beaches	beach	barren
Dry salt flats	dry_salt	barren

Sandy areas other than beaches	sandy	barren
Strip mines, quarries, and gravel pits	mine	barren
Transitional areas	transition	dev_hi, dev_med, dev_lo, shrub
Bare exposed rock	rock	barren
Mixed barren land	mix_barren	barren
Tundra		
Herbaceous tundra	herb_tun	grass, barren, shrub
Bare tundra	bare_tun	ice
Wet tundra	wet_tun	herb_wetland
Mixed tundra	mix_tun	No specific variable[C]
Perennial Snow or Ice		
Perennial snowfields	snowfield	ice
Glaciers	glacier	ice
Other		
Not specified (usually outside US boundaries: ocean, Mexico, or Canada)	unspec	
The minimum distance to an area designated “Commercial and Services”[a]	m_to_comm	

[a] Provided as a “distance” variable, not as land use in a buffer

[b] Mixture of developed, agricultural, and natural areas

[c] Mixture of categories

Table 13. Land use variable names (rlu_<type>_p<radius>) for variables calculated from satellite-imagery rasters

Variable Description	Variable Name (<type>)
Open water	water
Perennial ice, snow	ice
Developed open space	dev_open
Developed low intensity	dev_lo
Developed medium intensity	dev_med
Developed high intensity	dev_hi
Bare rock, sand, barren, mine	barren
Deciduous forest	decid_forest
Evergreen forest	evergreen
Mixed forest	mix_forest
Shrubland	shrub
Grasslands, herbaceous vegetation	grass
Pasture, hay	pasture
Cultivated crops such as orchards, vineyards, grains	crop
Woody wetlands	woody_wetland
Emergent, herbaceous wetland	herb_wetland

1.9.4 TeleAtlas Road Data

TeleAtlas road data were obtained from the EPA for the year 2000. These road networks had duplicate road segments in some areas. That is, two road segments with the same name and other identifying information were occasionally found to lie one right on top of the other. These were considered digitization errors and were removed with ArcGIS via python code.

Feature class codes are used to categorize roadways. Limited access highways are designated as A1 roads. Other major roads, such as state and county highways without limited access, are designated as A2 or A3 roads. More detailed information about the road classification system used in our database can be found at http://www.maris.state.ms.us/pdf/CFCCcodes.pdf.

1.9.5 Distance to Road and Near Road Determination

The perpendicular distance from locations to A1, A2, and A3 roads was calculated, based on the TeleAtlas road network and the geocoding of addresses as specified in section 2.4. Locations are considered 'near road' if the distance to and A1 or A2 is less than 100 meters, or if the distance to an A3 is less than 50 meters.

1.9.6 Sum of line lengths in buffers

The total length of A1, A2, and A3 roads was calculated in various buffer sizes, based on the TeleAtlas road network and the geocoding of addresses as specified in section 2.4. For example, if multiple A3 roads were present within the buffer, the total length of all segments that were contained within the buffer were summed. See Figure 1 for an illustration. These values are provided in units of meters and variables have the format ll_<road type>_s<buffer radius in m>.

1.9.7 Airports and Major Airports

Airport shapefiles and airport emission sums are obtained from NEI database. Runways of airports are subsetted, and centroids of runways were calculated. Emissions in tons and freight numbers were then

merged to centroids of runways and projected into appropriate State Plane projections. Airports were classified as "major" according to the number of passengers per year served by the airport and by the freight tonnage. A value of approximately 8,000 passengers per year was determined to be the approximate center of the distribution of passenger volumes among all airports in the study area. Approximately 160,000 pounds per year was determined to be the approximate center of the distribution for freight. Airports reporting passenger volumes or freight tonnage above these values, and all international airports, were considered major airports. Therefore, distance to major (large) airport (m_to_l_airp) was calculated separately from the distance to any airport (m_to_airp).

1.9.8 Coastlines, Railroads, and Rail Yards

Coastlines, railroads, and rail yard locations were obtained from the TeleAtlas geodatabase.

1.9.9 Ports

Port locations were obtained from the World Port Index from the National Imagery and Mapping Agency (now the National Geospatial Intelligence Agency). The designations of 'small', 'medium', and 'large' are made by that agency. The documentation says only that "the classification of harbor size is based on several applicable factors, including area, facilities, and wharf space. It is not based on area alone or on any other single factor."

1.9.10 Distance to Nearest Truck Route and Length of Truck Routes in Buffers

Truck route data was obtained from the National Transportation Atlas Database 2009 for data collected in 2008. The distance to the nearest truck route in meters is provided (m_to_truck). Truck route lengths in buffers were also summed (tl_s<radius>), in the same manner as road lengths.

1.9.11 Population

Population buffers are provided as the estimated total number of people living within the specified area as of the year 2000 census, calculated by multiplying a blockgroup population density by the area of the blockgroup lying within the buffer area and then taking the sum. Population data at the block group level is obtained from US Census Bureau for the year 2000 and block group boundaries are extracted from TeleAtlas database. Data from these two sources are then merged together by blockgroup key to create a new shapefile. This shapefile is then split into a series of shapefiles based on its designated State Plane projection. New columns are added to calculate area of each block group polygon in km^2 and then to calculate the population density in number of persons per km^2. Points locations are buffered, and the population densities and areas of the block groups within the buffer are used to calculate the total number of individuals within certain radii (measured in meters). These variables appear in the database with names such as pop_s01000.

1.9.12 Emissions Data

EPA's Emission Inventory and Analysis Group prepares a national database, the National Emission Inventory (NEI), of air emissions information with input from numerous State and local air agencies, from tribes, and from industry. The NEI database includes estimates of facility–specific Criteria Air Pollutants (CAPs) and Hazardous Air Pollutants (HAPs) emissions, along with their source-specific parameters necessary for modeling, such as location and facility characteristics (stack height, exit velocity, temperature, etc.). The latest and most updated NEI data available is the third and final version of the 2002 NEI data posted in January 2008. Using these data, the EAC sums the total tonnage of NO_X, SO_2, $PM_{2.5}$, PM_{10}, and CO emitted from short stacks within 3 km and from tall stacks between 3km and

15 km or 30 km of locations of interest. Facilities having stack heights of at least 30 meters (98.425 feet) are considered “tall” stack facilities. The rest are considered “short” stack facilities.

Table 14. Emissions variable names

Variable Description	Variable Name
Sum of major emissions from short stacks within 3 km	em_NOx_s03000, em_SO2_s03000, em_PM25_s03000, em_CO_s03000, em_PM10_s03000
Sum of major emissions from tall stacks within 15 km, minus the emissions from tall stacks within 3 km	em_NOx_s15000, em_SO2_s15000, em_PM25_s15000, em_CO_s15000, em_PM10_s15000
Sum of major emissions from tall stacks within 30 km, minus the emissions from tall stacks within 3 km	em_NOx_s30000, em_SO2_s30000, em_PM25_s30000, em_CO_s30000, em_PM10_s30000

1.9.13 Normalized Difference Vegetation Index

NDVI was obtained as a series of 16-day composite satellite images from the year 2006. The index was converted by the University of Maryland from the -1 to 1 scale to the 0-255 (pixel brightness) scale. On this scale, water has a value of approximately 50 and areas with dense vegetation have values around 200. For each location of interest, for each image, all pixels with a centroid within a certain distance of the location were averaged (radii included 250m, 500m, 1km, and 5km). For each buffer size, five summary numbers were calculated from the series of 23 averages for each location: the 25th, median, and 75th percentile of the entire year's series, the median of the expected 'high vegetation' season, defined as April 1 - September 30, and the median of the expected 'low vegetation' season, defined as the rest of the year.

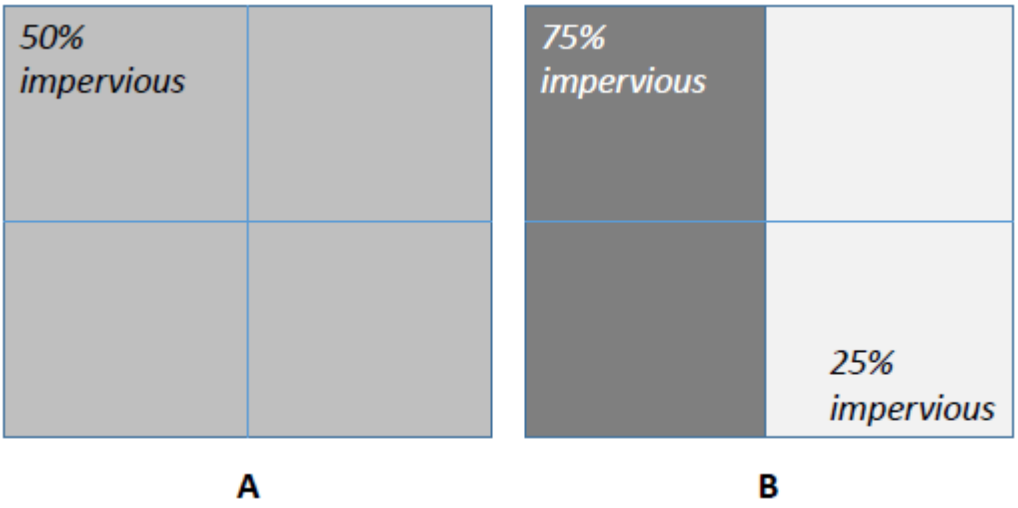
Table 15. NDVI variable names

Variable Description	Variable Name
25th percentile of entire year	ndvi_q25_a<radius>
Median of entire year	ndvi_q50_a <radius>
75th percentile of entire year	ndvi_q75_a<radius>
Median of April through September	ndvi_summer_a<radius>
Median of January through March and October through December	ndvi_winter_a<radius>

1.9.14 Impervious Surface

Impervious surface was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium’s National Landcover Dataset. Imperviousness was calculated by the MRLC from Landsat 7 Enhanced Thematic Mapper Plus (ETM+) satellite imagery. Briefly, the MRLC uses regression tree methods and the reflectance of different wavelengths of energy that are measured by satellite to characterize land cover. Image data are from 2006. Imperviousness refers to the percentage of area in a pixel that is covered with an impervious surface, such as pavement or concrete. Covariates provided by the EAC are averages of pixel values within various radii.

Figure 2. Each pixel in the impervious surface raster is assigned a value according to the permeability of the surfaces in that pixel. We provide the average pixel value within a buffer. In the illustration, both A and B have the same average value (50%).



1.9.15 Motor Vehicle Emissions Trends

Modeling was performed using the Motor Vehicle Emission Simulator 2014 (MOVES2014) software package[3] for 10 parameters in 21 counties that cover the MESA Air study areas. These parameters were: CO, NO_2, NO_X, Total $PM_{2.5}$, PM_{10} and $PM_{2.5}$ from brake wear, PM_{10} and $PM_{2.5}$ from tire wear, EC, Non-EC PM, sulfate, aerosol H_2O, and total energy expended by vehicles.

Vehicle types were classified into two distinct categories. These categories were broadly labeled "Heavy Duty Vehicles" and "Light Duty Vehicles." Only the contribution of vehicles travelling on urban restricted access and urban unrestricted access road types were considered in this analysis. Each possible combination of road type and vehicle type were paired and run separately.

Table 16. Classification of vehicle types

Light Duty Vehicles
Light Commercial Truck
Motor Home
Motorcycle
Passenger Car
Passenger Truck
Heavy Duty Vehicles
Combination Long-haul Truck
Combination Short-haul Truck
Intercity Bus
Refuse Truck
School Bus
Single Unit Long-haul Truck
Single Unit Short-haul Truck

[3] EPA Office of Transportation and Air Quality

Monthly values are available for the parameters by county for the years 1990 and 1999-2014, by vehicle/access category (light duty restricted access, light duty unrestricted access, heavy duty restricted access, heavy duty unrestricted access).

1.9.16 Residual Oil in New York City

Residual oil boilers are associated with high emissions of soot and of some elements (e.g., sulfur and nickel). Such boilers are common in the New York City metropolitan area. They are used in medium-to-large apartment buildings and in institutions such as hospitals and colleges. Most of the emission is usually through roof chimneys, rather than at street level. Residual oils graded 4 and 6 are the heaviest fractions of petroleum distillation, with 6 being heavier and dirtier.

Data were received from Environmental Defense Fund (EDF), who transferred the information to the public domain via a FOIA from New York City government. Data were cleaned of a few gross location and BTU-capacity errors. Boiler locations were geocoded by the MESA-Air EAC. Only boilers installed prior to 2007 were included (>95% of the original EDF dataset).

Table 17. Residual oil variable names

Variable Description	Variable Name
Meters to nearest residual oil grade 4 or 6 boiler; censored between 30m and 2000m	m_to_oil
Meters to nearest Residual Oil 6 boiler; censored between 30m and 2000m	m_to_6oil
Sum of total residual oil active heating capacity (in Mega-BTU per hour)	oil_edf<oil grade>_s<radius>

1.9.17 Elevation

Each MESA location point had an elevation value in meters extracted from a National Elevation Dataset (NED)-based raster grid, provided by the USGS. In the continental US and Hawai'i, the resolution of the raster was 1 arc second. The resolution was 2 arc seconds for Alaska. A concentric set of twenty four elevation points were then generated around each location point for a statistical sample at two radii (1000 m. and 5000 m). Standard deviation and counts of "above" or "below" a threshold elevation (+/- 20 or 50 meters respectively) were calculated for each point utilizing the twenty four point sampling.

Table 18. Elevation variable names

Variable Description	Variable Name
Elevation above sea level in meters	elev_elevation
Standard deviation of elevation of twenty points surrounding location	elev_1k_stdev, elev_5k_stdev
Count of points (out of 24) within 20m of the same elevation	elev_1k_at_elev
Count of points (out of 24) more than 20m uphill or downhill of the location	elev_1k_above, elev_1k_below
Count of points (out of 24) within 50m of the same elevation	elev_5k_at_elev
Count of points (out of 24) more than 50m uphill or downhill of the location	elev_5k_above, elev_1k_below

A small number of other statistics were calculated regarding the points surrounding the locations. These statistics are not anticipated to be useful for general modeling applications and will not be distributed as part of the set of standard covariates. Users interested in creating a more sophisticated model for the effect of elevation should contact the EAC for more details.

1.9.18 Urban Topography

Building footprints, heights and parcel information were obtained for Chicago and New York City, from the respective city governments (see Table 11 for data source details). Statistics were calculated in an effort to characterize the degree to which each location in these two cities is situated in a "Street Canyon" (i.e., surrounded by buildings in a manner that significantly constrains air flow). If these data are missing for any specific location in NYC or Chicago, this indicates that no building was found within 60m of that location.

Generally speaking, individual urban topography variables do not directly quantify the pollution exposure exacerbation due to street canyons. They serve as building blocks for street canyon models currently under development and can be provided to analysts with a specific use for them. However, they are not intended to be distributed with the 'standard set' of modeling variables.

Table 19. Urban topography variable names

Variable Description	Variable Name
Distance in meters from the location's geocode to the closest building. That building is the reference for all subsequent calculations. If the geocode falls within a building's polygon, the distance is set at 1m. Maximum hit distance is 60m.	canyon_bldg_hitdist
Height of reference building in floors	canyon_bldg_hgt
Distance-weighted mean height of buildings on the same block on the same side of the street or of the buildings on the opposite side of the street (in floors). Open space is included as zero.	canyon_bldg_meanflrs, canyon_opp_meanflrs
The length of the block, measured as the distance in meters between the two road intersections defining it.	canyon_road_len
CFCC type of the road in the middle of the canyon, i.e. A2, A3, A4	canyon_road_type
Binary; 1 indicates that building is at the block's end	canyon_iscorner
Binary; 1 indicates that there is no opposite building	canyon_opp_missing

1.9.19 Census Data

Census data for the year 2000 were obtained from the US Census via the University of Washington Library. These demographic variables are included in the Census' Summary File 3 (SF 3). Data were compiled at the block (bk), block group (bg), and tract (tr) aggregating levels.

Table 20. 2000 Census variable names

Variable Description	Variable Name
Geographic Identifiers	
(Consolidated) Metropolitan Statistical Area Code, used by OMB for federal statistical agencies	cmsa
Race/Ethnicity (Self-Identified)	
% White alone	<level>_p_race_white**
% Black or African American alone	<level>_p_race_black
% American Indian and Alaska Native alone	<level>_p_race_native_amer
% Asian alone	<level>_p_race_asian
% Native Hawaiian and Other Pacific Islander alone	<level>_p_race_pacific
% Some other race alone	<level>_p_race_other
% Two or more Races	<level>_p_race_multi
% Hispanic	<level>_p_ethn_hisp
% Non-Hispanic	<level>_p_ethn_non_hisp
% Non-Hispanic Black	<level>_p_ethn_non_hisp_black
% Non-Hispanic White	<level>_p_ethn_non_hisp_white
Marital Status for the population 15+ (Self Identified)	
% Never married*	<level>_p_marital_never
% Now married*	<level>_p_marital_current
% Widowed*	<level>_p_marital_widow
% Divorced*	<level>_p_marital_divorce
Income	
Median Household Income ($)*	<level>_med_inc_hshld
Mean Household Income ($)*	<level>_mean_inc_hshld
Median Family Income ($)*	<level>_med_inc_family
Mean Family Income ($)*	<level>_mean_inc_family
% Households with income < $15,000/year*	<level>_p_inc_hshld_le_15k
% Households with income >$150,000/year*	<level>_p_inc_hshld_ge_15k
% Households with income < $25,000/year*	<level>_p_inc_hshld_le_25k
% Households with income < $50,000/year*	<level>_p_inc_hshld_le_50k
% Households with income < $100,000/year*	<level>_p_inc_hshld_le_100k
% Households with income < $150,000/year*	<level>_p_inc_hshld_le_150k
% Households with income < $200,000/year*	<level>_p_inc_hshld_le_200k
% of the population aged 5+ years who are below the poverty line*	<level>_p_poverty_individual
% of families who are below the poverty line*	<level>_p_poverty_family
% of households who are below the poverty line*	<level>_p_poverty_hshld
Employment	
% of the civilian population aged 16+ years that is unemployed*	<level>_p_unemp_all
% of the civilian male population aged 16+ years that is unemployed*	<level>_p_unemp_male
Occupation	
% Employed civilian population 16+ in each of the following categories	
Management, Professional, and related occupations*	<level>_p_emp_professional

Manager Occupations	<level>_p_emp_manager
Service occupations*	<level>_p_emp_service
Sales and office occupations*	<level>_p_emp_sales
Farming, fishing, and forestry occupations*	<level>_p_emp_farm_fish
Construction, extraction, and maintenance occupations*	<level>_p_emp_construction
Production, transportation, and material moving occupations*	<level>_p_emp_transport
Housing	
% Total housing units that are occupied	<level>_p_housing_occ
% Occupied housing units that are owner-occupied (vs. renter-occupied)	<level>_p_housing_owner_occ
% Occupied housing units with >1 person per room*	<level>_p_housing_crowded
Median value ($) for specified owner-occupied housing units*	<level>_med_housing_value
% of the population that has lived at the same residence for 5+ years – tract only	tr_same_resi_5_yr
Household Size of Occupied Housing Units	
% of occupied housing units with a 1-person household	<level>_p_hshld_1
% of occupied housing units with a 2-person household	<level>_p_hshld_2
% of occupied housing units with a 3-person household	<level>_p_hshld_3
% of occupied housing units with a 4-person household	<level>_p_hshld_4
% of occupied housing units with a 5-person household	<level>_p_hshld_5
% of occupied housing units with a 6-person household	<level>_p_hshld_6
% of occupied housing units with a 7-or-more-person household	<level>_p_hshld_7plus
Urbanicity	
% of the population living in an urban area – tract only	tr_p_pop_urban
% of the population living in a rural area – tract only	tr_p_pop_rural
Education	
% Adults 25+ with < High School*	<level>_p_edu_less_hs
% Adults 25+ with ≥ High School*	<level>_p_edu_ge_hs
% Adults 25+ with High School diploma or equivalency*	<level>_p_edu_hs
% Adults 25+ with Some College, No Degree*	<level>_p_edu_some_college
% Adults 25+ with Associate's Degree*	<level>_p_edu_aa
% Adults 25+ with Bachelor's Degree*	<level>_p_edu_ba
% Adults 25+ with Master's Degree*	<level>_p_edu_ma
% Adults 25+ with Professional School Degree*	<level>_p_edu_professional
% Adults 25+ with Doctorate Degree*	<level>_p_edu_phd
* Not available at the block level ** Where level is either block (bk), block group (bg), or tract (tr)	

Census data is also available for 2010. After the 2000 Census, the Census Bureau began administering the long-form questionnaire on a rolling (yearly) basis through the American Community Survey (ACS). The Census only releases ACS data for small areas in in five-year aggregations, and so we provide ACS data from the period 2006 through 2010 for tracts and block groups. Block-level data are more restricted, and therefore short-form (SF1) 2010 data are provided. 2010 data was retrieved through the

National Historical Geographic Information System[4] (***http://www.nhghis.org/***) and from Social Explorer (***http://www.socialexplorer.com/***). All dollar figures were reported in 2010 inflation-adjusted dollars. More variables, years, and geographic areas are publicly available through these websites and through ***http://www.census.gov/***.

Table 21. Year 2010 census variable names

Variable Description	Variable Name	Availability
Basic Demographics		
Total Population	<level>_tot_pop_2010*	All
Area (land only) in Square Kilometers	<level>_land_area_sqkm	All
% Male	<level>_p_sex_male	All
% Female	<level>_p_sex_female	All
% Under 5 years	<level>_p_age_0_5	All
% 5 to 9 years	<level>_p_age_5_9	All
% 10 to 14 years	<level>_p_age_10_14	All
% 15 to 17 years	<level>_p_age_15_17	All
% 18 to 24 years	<level>_p_age_18_24	All
% 25 to 34 years	<level>_p_age_25_34	All
% 35 to 44 years	<level>_p_age_35_44	All
% 45 to 54 years	<level>_p_age_45_54	All
% 55 to 64 years	<level>_p_age_55_64	All
% 65 to 74 years	<level>_p_age_65_74	All
% 75 to 84 years	<level>_p_age_75_84	All
% 85 years and over	<level>_p_age_85_plus	All
Race/Ethnicity		
% White alone	<level>_p_race_white	All
% Black or African-American alone	<level>_p_race_black	All
% American Indian and Alaska native alone	<level>_p_race_native_amer	All
% Asian alone	<level>_p_race_asian	All
% Native Hawaiian and other Pacific Islander alone	<level>_p_race_pacific	All
% Some other race alone	<level>_p_race_other	All
% Two or more races	<level>_p_race_multi	All
% Hispanic	<level>_p_ethn_hisp	All
% Non-Hispanic	<level>_p_ethn_non_hisp	All
% Non-Hispanic: white alone	<level>_p_ethn_non_hisp_white	All
% Non-Hispanic: black or African-American alone	<level>_p_ethn_non_hisp_black	All
Native/Foreign Born		

[4] Minnesota Population Center. *National Historical Geographic Information System: Version 2.0*. Minneapolis, MN: University of Minnesota 2011.

% Native born	<level>_p_born_native	TR
% Foreign born	<level>_p_born_foreign	TR
% of Foreign born: naturalized citizen	<level>_p_born_foreign_naturalized	TR
% of Foreign born: not a citizen	<level>_p_born_foreign_noncitizen	TR
Households and Families		
Households	<level>_households	All
Families	<level>_families	All
Housing units	<level>_housing	All
Housing units: occupied	<level>_housing_occ	All
Housing Characteristics		
% Occupied housing units: owner occupied	<level>_p_housing_occ_owner	All
% Occupied housing units: renter occupied	<level>_p_housing_occ_renter	All
% Occupied housing units: House heating fuel: gas (utility, bottled, tank, or LP gas)	<level>_p_housing_fuel_gas	TR, BG
% Occupied housing units: house heating fuel: electricity	<level>_p_housing_fuel_elec	TR, BG
% Occupied housing units: house heating fuel: fuel oil, kerosene, etc.	<level>_p_housing_fuel_oil	TR, BG
% Occupied housing units: house heating fuel: coal, coke or wood	<level>_p_housing_fuel_wood	TR, BG
% Housing units: 1 unit	<level>_p_housing_units_1	TR, BG
% Housing units: 2	<level>_p_housing_units_2	TR, BG
% Housing units: 3 or 9	<level>_p_housing_units_3_9	TR, BG
% Housing units: 10 to 49	<level>_p_housing_units_10_49	TR, BG
% Housing units: 50 or more	<level>_p_housing_units_50_plus	TR, BG
% Housing units: Mobile home	<level>_p_housing_units_mobile	TR, BG
% Housing units: Boat, RV, van, etc.	<level>_p_housing_units_other	TR, BG
Median year structure built	<level>_housing_med_yr_built	TR, BG
Owner-occupied housing units: median value	<level>_med_housing_value	TR, BG
Income		
Median household income (In 2010 Inflation adjusted dollars)	<level>_med_inc_hshld	TR, BG
Average household income (In 2010 Inflation adjusted dollars)	<level>_mean_inc_hshld	TR, BG
Median family income (In 2010 Inflation adjusted dollars)	<level>_med_inc_family	TR, BG
Average family income (In 2010 Inflation adjusted dollars)	<level>_mean_inc_family	TR, BG
% Households with Income Less than $15,000	<level>_p_inc_hshld_le_15k	TR, BG

% Households with Income Less than $25,000	<level>_p_inc_hshld_le_25k	TR, BG
% Households with Income Less than $50,000	<level>_p_inc_hshld_le_50k	TR, BG
% Households with Income Less than $100,000	<level>_p_inc_hshld_le_100k	TR, BG
% Households with Income Less than $150,000	<level>_p_inc_hshld_le_150k	TR, BG
% Households with Income Less than $200,000	<level>_p_inc_hshld_le_200k	TR, BG
Marital Status		
% Population 15 years and over: never married	<level>_p_marital_never	TR, BG
% Population 15 years and over: now married (not including separated)	<level>_p_marital_current	TR, BG
% Population 15 years and over: separated	<level>_p_marital_sep	TR, BG
% Population 15 years and over: widowed	<level>_p_marital_widow	TR, BG
% Population 15 years and over: divorced	<level>_p_marital_divorce	TR, BG
Employment		
% Population 16 years and over: in labor force	<level>_p_labor_force	TR
% Civilian population 16 years and over in labor force: unemployed	<level>_p_unemp_all	TR
% Civilian male population 16 years and over in labor force: unemployed	<level>_p_unemp_male	TR
% Employed civilian population 16 years and over: agriculture, forestry, fishing and hunting, and mining	<level>_p_emp_farm_fish	TR
% Employed civilian population 16 years and over: construction	<level>_p_emp_construction	TR
% Employed civilian population 16 years and over: manufacturing	<level>_p_emp_manufacturing	TR
% Employed civilian population 16 years and over: wholesale trade	<level>_p_emp_trade_whole	TR
% Employed civilian population 16 years and over: retail trade	<level>_p_emp_trade_retail	TR
% Employed civilian population 16 years and over: transportation and warehousing, and utilities	<level>_p_emp_transportation	TR
% Employed civilian population 16 years and over: information	<level>_p_emp_information	TR
% Employed civilian population 16 years and over: finance and insurance, and real estate and rental and leasing	<level>_p_emp_financial	TR

% Employed civilian population 16 years and over: professional, scientific, and management, and administrative and waste management services	<level>_p_emp_pro	TR
% Employed civilian population 16 years and over: educational services, and health care and social assistance	<level>_p_emp_edu_health	TR
Employed civilian population 16 years and over: arts, entertainment, and recreation, and accommodation and food services	<level>_p_emp_food_leisure	TR
% Employed civilian population 16 years and over: public administration	<level>_p_emp_public	TR
% Employed civilian population 16 years and over: Other services, except public administration	<level>_p_emp_other	TR
Education		
% Civilian population 16 to 19 years: not high school graduate, not enrolled (dropped out)	<level>_p_edu_teen_dropout	TR, BG
Population 25 years and over: less than high school	<level>_p_edu_less_hs	TR, BG
Population 25 years and over: high school graduate (includes equivalency)	<level>_p_edu_ge_hs	TR, BG
Population 25 years and over: some college	<level>_p_edu_some_college	TR, BG
Population 25 years and over: bachelor's degree	<level>_p_edu_bs	TR, BG
Population 25 years and over: master's degree	<level>_p_edu_ma	TR, BG
Population 25 years and over: professional school degree	<level>_p_edu_professional	TR, BG
Population 25 years and over: doctorate degree	<level>_p_edu_phd	TR, BG
Poverty Status		
Population for whom poverty status is determined: Under 1.00	<level>_p_poverty_income_ratio_0_99	TR, BG
Population for whom poverty status is determined: 1.00 to 1.99	<level>_p_poverty_income_ratio_100_199	TR, BG
Population for whom poverty status is determined: 2.00 and over	<level>_p_poverty_income_ratio_200_plus	TR, BG
Families with income below poverty level	<level>_p_povery_families	TR, BG
Urbanicity		
Urban/rural designation	urban_rural	BK

* Where level (see last column) is either block (bk), block group (bg), or tract (tr)

1.9.20 Distance to Bus Route

Bus route data was obtained through contact with the New York Department of Transportation and included bus route information for the New York City area including routes in New York, New Jersey, and Connecticut. The distance to the nearest bus route in meters is provided (m_to_bus). Bus route lengths in buffers were also summed (bus_s<radius>), in the same manner as road lengths.

Bus routes for other areas of the US will be added in the future. These data were downloaded from GTFS Feeds (http://transitfeeds.com/) in October 2016. GIS software was used to reproject into state plane zones, dedup links, and remove non-bus transportation types (ferry, light rail).

1.9.21 Satellite Data: PM2.5, NO2, SO2, HCHO, CO

Satellite-based estimates of air pollution for PM2.5, NO2, SO2, CO, and formaldehyde (HCHO) were obtained.

Annual satellite-based estimates of ground-level PM2.5 (1998-2014) at 0.1° were obtained from a previously published, publicly available data set (van Donkelaar et al., 2016). Briefly, five aerosol optical depth (AOD) satellite retrievals were combined with (1) satellite-based measurements of vertical aerosol profiles, (2) modeled AOD and ground-level PM2.5 from a global chemical transport model (GEOS-Chem), and (3) ground-based AOD measurements from the aerosol robotic network (AERONET) to estimate annual ground-level PM2.5 on a 0.1° grid (van Donkelaar et al., 2016).

We obtained daily L2 surface-level CO from the Measurements of Pollution in The Troposphere (MOPITT) sensor on NASA's Terra satellite for years 2001-2016 (Deeter et al., 2017). Tropospheric NO2, SO2, and HCHO were derived from daily measurements obtained by the Ozone Monitoring Instrument (OMI) onboard the NASA Earth Observing System (EOS)-Aura satellite. Measurements were screened for quality based on cloud cover, illumination, and data flags and averaged temporally following a standard method for satellite data that considers pixel values within a buffer. The resolution of the final, processed rasters is provided in the table below.

The value of the covariate in each case is the value of the pixel/grid cell in which the location lies.

Table 22. Satellite data methods

Pollutant	Years	Resolution	Instrument	Surface/Column
$PM_{2.5}$	1998 – 2016	0.1°	Multiple instruments	Surface
NO_2[a]	2005 – 2016	0.1°	OMI	Column
SO_2	2005 – 2016	0.25°	OMI	Column
HCHO[b]	2005 – 2016	0.1°	OMI	Column
CO	2001 – 2016	0.25°	MOPITT	Surface

[a]both 1-year and 3-year averages calculated; [b]long term (12-year) average only

1.9.22 Method of Covariate (Variable) Calculation

Calculations were performed using the PostGIS spatial extension to PostgreSQL. Relevant scripts are located in Q:\neogeo and archived on github (https://github.com/kaufman-lab/neogeo).

All distance calculations are truncated at 25 kilometers, except for distance to A2 or A3 which were truncated at 20 kilometers. For example, the distance to the nearest coastline will be 25,000 meters for

all locations in the Winston-Salem study area, as well as those locations in the Los Angeles study area that are greater than 25 kilometers from the coast. Data users should be aware that this will be true whether the location is 25.1 kilometers from the coast or 100 kilometers from the coast.

1.9.23 Data Quality

The EAC does not perform QC on the source shapefiles that were downloaded from third-party data providers. Data quality as reported by the data generating agency is disclosed in the metadata document and discussed in the MESA Air Quality Assurance Project Plan (see Appendix C).

1.10. Exposure Model Outputs

Modeled pollutant estimates may lag behind location data corrections by one database revision. Therefore, locations may not be assigned the estimate produced for an old location that lies more than 10m from the updated location.

For pollutants modeled at the two-week time resolution, an annual average will not be distributed for a participant that has fewer than 25 two-week predictions available for the residences at which they lived during the time period of interest. This could happen if, for example, a participant lived outside the MESA Air modeling areas during part of the year prior to their exam.

Table 23. Availability of predictions in MESA Air and SPIROMICS modeling regions (and WHICAP). For participant locations, predictions are generated for all addresses geocoded to intersections or exact locations. Models are maximum-likelihood based, unless otherwise indicated. Cells indicate the database version providing the underlying covariate data.

Pollutant	Dates Available and Temporal Resolution	MESA Air	Regional Grids	Fine-Scale Grids	SPIROMICS Air[g]	MESA Air/ SPIROMICS Air/ WHICAP[f]
$PM_{2.5}$ ($\mu g/m^3$)	01/1999 – 12/2018	Rev 12	Rev 8	Rev 8	Rev 12	Rev 14
NO_X (ppb)	01/1999 – 12/2018	Rev 12	Rev 8	Rev 8	Rev 12	Rev 14
NO_2 (ppb)	01/1999 – 12/2018	Rev 12	Rev 8	Rev 8	Rev 12	Rev 14
LAC ($10^{-5}m^{-1}$)	2005 – 2009 at 2-wk resolution and spatial-only representing 2006 – 2008	Rev 8	Rev 8	Rev 8	----	----
O_3 (ppb)	01/1999 – 12/2018	Rev 12	Rev 9	Rev 9	Rev 12	Rev 14
LUR-based Coarse $PM_{10-2.5}$ ($\mu g/m^3$), Cu (ng/m^3), P (ng/m^3), Si ($\mu g/m^3$), Zn (ng/m^3)	Spatial only (meant to represent the 2009 annual average)	Rev 3, available only for participants in Chicago, Winston-Salem and St. Paul[b]	Rev 3	----	----	----
Individual-level $PM_{2.5}$ exposure (integrating infiltration and time-location) ($\mu g/m^3$)	Specific to residence at time of Air Questionnaire	Rev 5[d]	----	----	----	----
Pragmatic $PM_{2.5}$ (AKA "Interim Pragmatic")[a] ($\mu g/m^3$)	1999 – 2006 at 2-wk resolution; available only for baseline addresses	Prior to development of the EAC database	----	----	----	----
Pragmatic $PM_{2.5}$ (AKA "Final Pragmatic")[a] ($\mu g/m^3$)	1999 – 2009 at 2-wk resolution	Rev 0	----	----	----	----

[a] Not recommended for current use; superseded by more recent models.

[b] MESA Coarse modeling regions differ from standard MESA Air regions. MESA Coarse predictions are available within 25 km of monitors.

[d] This Rev is the time that the infiltration questionnaire table was created. Final exposures integrate the current version of ST model predictions.

[e] Ozone predictions from the SPIROMICS models start in 1/2002 for Winston-Salem, 1/2006 for Salt Lake City, and 4/2009 for Ann Arbor.

[f] Beginning from Rev 14, an "omnibus" version of city-specific modeling is implemented. This unifies the prediction process for all cohort locations in cities for which supplemental monitoring is available, namely Baltimore, New York City, Los Angeles, Winston-Salem, Chicago, St. Paul, Ann Arbor, Salt Lake City, and San Francisco.

[g] Indoor predictions are generally available for the same time period as the corresponding pollutant ($PM_{2.5}$, NO_X, NO_2) and nicotine from 1998-2016. Specific maximum date ranges are provided in the appendix, but predictions are only available for the specific address for which a participant completed the Home Information Questionnaire (HIQ), which is an address where they lived between 2014-2016.

Table 24. Availability of national model predictions. All national models are available at annual average resolution only, and only addresses within the continental US are included for any cohorts at this stage. Cells indicate the database version providing the underlying covariate data.

Pollutant	Years Available (all annual averages)	MESA Air	Sister, Two Sister	CHS/Other	WHI	National (Large-Scale) Grid
$PM_{2.5}$ ($\mu g/m^3$)	1999 – 2015	Rev 11	Rev 11	----	Rev 11	Rev 11
$PM_{2.5}$ ($\mu g/m^3$) (historical)	1980 – 2010	Rev 9	----	----	Rev 10	Rev 9
PM_{10} ($\mu g/m^3$)	1990 – 2014	Rev 11	Rev 11	Rev 11	Rev 11	Rev 11
Satellite NO_2 (Includes Satellite-based NO_2) (ppb)	1990 – 2014	Rev 11	Rev 11	Rev 11	Rev 11	Rev 11

1.10.1 NO_X, NO_2, and $PM_{2.5}$ Likelihood Model Predictions

The NO_X, NO_2, and $PM_{2.5}$ predictions use a spatio-temporal modeling methodology originally developed by Paul D. Sampson. It was first described in Fuentes et al.[5], and adapted to MESA Air's data systems by Sampson et al.[6]. The model is optimized via maximum likelihood, as developed and described by Szpiro et al.[7] Subsequently, Keller et al. (citation) implemented the full unified hierarchical spatiotemporal model for MESA Air data. Both monitoring data and geographical variables were extracted from MESA Air Exposure Assessment Center's database. All models are based on Version 14 (DR0328, September 2020) data for predictions from the beginning of 1999 through at least June 2018 for NO_2, July 2018 for $PM_{2.5}$, and January 2019 for NO_x. Beginning from Rev 14, an "omnibus" version of city-specific modeling is implemented. This unifies the prediction process for all cohort locations in cities for which supplemental monitoring is available, namely Baltimore, New York City, Los Angeles, Winston-Salem, Chicago, St. Paul, Ann Arbor, Salt Lake City, and San Francisco. Therefore, a single, more convenient and efficient modeling process produces predictions for MESA Air, SPIROMICS Air and WHICAP participants.

It is worth noting that, in addition to the data described in this document, and provided as part of the MESA Air Data Request System (V7 and above), models for pollutants NYC and Rockland include NYCCAS monitoring data. NYCCAS collected NO, NO_2, and $PM_{2.5}$ in New York City over a period of two years between December 2008 and December 2010. Samples were collected at 150 sites for 7 to 8 two-week periods (one per season per year) over the two year period. Five reference locations, one in each NYC borough, collected two-week samples for the entire two-year period[8].

The open-source R statistical analysis language was used, with the core model-fitting functions taken from the "SpatioTemporal" R package[9], authored by Lindstrom et. al.[10] and maintained by Lindstrom. The package is available on CRAN. Predictions were generated at all MESA Air participant addresses that were valid from 1999-2019, were within a modeling area, and were geocoded to an 'exact', 'block', or 'intersection' location. See appendix for modeling area and model performance statistics.

1.10.2 O_3 Likelihood Model Predictions

The O_3 models were originally developed by Meng Wang using equivalent methods to those used in the previous section. The current predictions are based on Version 14 data and run through at least March 2018.

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[5] Fuentes, Monteserrat and Guttorp, Peter and Sampson, Paul D., 2006. Using transforms to analyze space-time processes. In: Finkenstadt, B. and Held, L. and Isham, V., Statistical Methods for Spatio-Temporal Systems, CRC/Chapman and Hall, pp. 77-150.

[6] Paul D. Sampson, Adam A. Szpiro, Lianne Sheppard, Johan Lindström, and Joel D. Kaufman, "Pragmatic Estimation of a Spatio-Temporal Air Quality Model with Irregular Monitoring Data" (November 30, 2009). *UW Biostatistics Working Paper Series.* Working Paper 353. Available at: http://www.bepress.com/uwbiostat/paper353.

[7] Szpiro, Adam A., Sampson, Paul D., Sheppard, Lianne, Lumley, Thomas, Adar, Sara and Kaufman, Joel, 2010. Predicting intra-urban variation in air pollution concentrations with complex spatio-temporal dependencies. Environmetrics 21, 606-631.

[8] The New York City Department of Health and Mental Hygiene, Queens College Center for the Biology of Natural Systems, and Zev Ross Spatial Analysis.

[9] The NO_2 model was developed with version 0.6.0 of the package, and updated NO_X with version 0.9.2

[10] Johan Lindstrom, Adam Szpiro, Paul D. Sampson, Silas Bergen and Assaf P. Oron (2012). SpatioTemporal: Spatio-Temporal Model Estimation. R package version 0.9.2. http://CRAN.R-project.org/package=SpatioTemporal.

Again, the open-source R statistical analysis language was used, with the core model-fitting functions taken from the "SpatioTemporal" R package[11], authored by Lindstrom et. al.[12] and maintained by Lindstrom. The package is available on CRAN. Predictions were generated at all MESA Air participant addresses that were valid from 1999-2018, were within a modeling area, and were geocoded to an 'exact', 'block', or 'intersection' location. See appendix for modeling area and model performance statistics.

1.10.3 SPIROMICS-Specific Likelihood Model Predictions

Predictions were obtained using methods similar to those utilized in MESA-Air (described briefly in Section 1.12.1 above) following the operational details of the hierarchical spatiotemporal model in Keller at al. Monitoring data and geographical covariates were extracted from MESA Air Exposure Assessment Center's database for seven SPIROMICS cities (Baltimore, MD, New York, NY, Winston-Salem, NC, Los Angeles, CA, San Francisco, CA, Salt Lake City, UT, and Ann Arbor, MI, the first four of which were also MESA cities). After covariate pre-processing based on the recommendations in Keller et al., core model fitting was performed using SpatioTemporal, an R package available on CRAN. As indicated above, beginning from Rev 14, an "omnibus" version of city-specific modeling is implemented. This unifies the prediction process for all cohort locations in cities for which supplemental monitoring is available, namely Baltimore, New York City, Los Angeles, Winston-Salem, Chicago, St. Paul, Ann Arbor, Salt Lake City, and San Francisco. Therefore, a single, more convenient and efficient modeling process produces predictions for MESA Air, SPIROMICS Air and WHICAP participants. Predictions are based on a draft of Rev 14 of the data (DR0328, September 2020). Coverage periods are as indicated above for MESA Air. See the appendix for a summary of source monitors, modeling areas and model performance.

1.10.4 National Spatiotemporal Model Predictions - $PM_{2.5}$, NO_2, O_3,

The national spatiotemporal models are fit separately on 9 regions. Notably, the model is fit on Wednesday to Wednesday two-week periods, but due to inconsistent monitoring schedules between MESA monitoring campaigns, those two-week schedules are not the same in all regions. Therefore, these two-week predictions are split into into one-week predictions (by repeating the predictions for a given two week period into the two respective one week periods). This allows a consistent (one-week) prediction intervals even in region-overlap areas. Note that while one-week predictions exist in the database, the model is not reliable down to this one-week temporal scale and therefore the minimimal recommended averaging period is two weeks. Time-weigthed two-week predictions will incorporate monitoring data from adjacent (ie preceding or subsequent) two-week monitoring periods. In general, caution should be used when using short exposure averaging periods since there will be some amount of temporal measurement error.

Within each region, a model is fit similarly to city-specific spatiotemporal models, except that smoothing parameters are fit on only a subset of the long-term monitors to reduce computational time. To reduce obvious discontinuities at region borders, these regions were designed to be slightly overlapping (approximately 100km in either direction of region borders). Predictions in overlaps are made separately for both (or all) models in overlapping regions, then these predictions are distance-weighted to produce a single prediction for a given period. See appendix for summary of model performance.

[11] All models were developed with version 1.1.9.1 of the package.

[12] Johan Lindstrom, Adam Szpiro, Paul D. Sampson, Silas Bergen and Assaf P. Oron (2012). SpatioTemporal: Spatio-Temporal Model Estimation. R package version 0.9.2. http://CRAN.R-project.org/package=SpatioTemporal

1.10.5 Light Absorption Coefficient (LAC) Predictions

LAC predictions are available at MESA participants' residential locations. A spatio-temporal model for LAC was developed based on MESA Air monitoring data collected between July 2005 and July 2009, NYCCAS data from 2008 – 2010 for NYC and Rockland, and geocovariates from Rev 7 of the database. The model was fit using the SpatioTemporal R package, and predictions were averaged over the timeframe of MESA Air monitoring (2006-2008). The spatial averages from the model are intended to represent long term exposures to black carbon. See appendix for model performance statistics.

1.10.6 National Model $PM_{2.5}$, PM_{10}, and NO_2 Predictions

The national models for $PM_{2.5}$, PM_{10} and NO_2 are universal kriging models with partial least squares used to select relevant components for the mean regression. In Rev 9, we additionally include an alternative national NO_2 national model that includes as an independent predictor variable columnar satellite NO_2 measurements. This model showed improved performance compared to the model without satellite data and is the recommended exposure. The nation was divided into three regions based on topography. Each model was fit as a whole using maximum likelihood, with each region having its own set of estimated parameters for each pollutant and year. That is, for each year of annual average monitoring data, models were separately estimated (meaning that for each year PLS components, PLS coefficients, and variograms were estimated separately). Predictions were generated for all participant residence locations. The method was developed by Paul Sampson et. al. and implemented by Michael Young and Josh Keller[13]. $PM_{2.5}$ (1999-2011) is based on Version 5 (August 2012) data, PM_{10} (1990-2010) is based on Version 6 (February 2013) data, NO_2 (1990-2012) is based on Version 7 (August 2013), and satellite-enhanced NO_2 (1990-2012) is based on Version 8 data. Models through 2014 (NO2) or 2015 ($PM_{2.5}$) were added in Rev 11. Models for 2014-2016 were added for PM_{10} in Rev 14. See appendix for model performance statistics.

1.10.7 National Model Historical $PM_{2.5}$ Predictions

The model for historical PM2.5 Predictions relies on the MESA Air spatio-temporal modeling framework applied to annual average concentrations. See section 2.12.1 for a summary of these methods. Models were built using Version 6 covariates (DR0110). Temporal trends were back-casted using line extrapolation of trends estimated from 1999-2012 data. Historical prediction models were developed by Sun-Young Kim.[14] See appendix for model performance statistics.

1.12.8 Coarse PM Land Use Regression Predictions

Model predictions for the MESA Coarse PM Study were developed for $PM_{10-2.5}$, Cu, Si, P, and Zn using monitoring data collected at Coarse Snapshot locations (see section 2.3.1) and covariates from Rev 2 (DR0056). Land use regression models were selected using a separate exhaustive search for each study area and pollutant for the model with the lowest RMSE. Variable selection for the candidate models is described in Zhang et. al. (submitted). Briefly, models were designed to accommodate monitoring data from two rounds of sampling with interaction terms for season. The variable list was pared down from the available set described in section 2.10 to include those covered adequately by both the monitored locations and participant locations, then further reduced to 15 using LASSO. Kriging was not supported

[13] Paul David Sampson, Mark Richards, Adam A Szpiro, Silas Bergen, Lianne Sheppard, Timothy V Larson, Joel D Kaufman, 2013. A Regionalized National Universal Kriging Model using Partial Least Squares Regression for Estimating Annual PM2.5 Concentrations in Epidemiology. Atmospheric Environment 75, 383-392.

[14] Kim SY, Olives C, Sheppard L, Sampson PD, Larson TV, Keller JP, Kaufman JD. Historical prediction modeling approach for estimating long-term concentrations of PM2. 5 in cohort studies before the 1999 implementation of widespread monitoring. Environmental health perspectives. 2017 Jan;125(1):38.

by the monitoring data and was not used. Predictions for locations lying more than 25 km from a monitoring location or with covariate values lying outside the range observed in the monitoring locations (with a 10% tolerance) were flagged. By default, these predictions are excluded from datasets provided to analysts. Note that this means that 'missing' predictions will vary by pollutant. See appendix for model performance statisics.

1.10.9 Individual-level Exposures to Ambient $PM_{2.5}$

Ambient source exposures incorporate the likelihood-based $PM_{2.5}$ predictions, predicted infiltration fractions, and time-location questionnaire data. The fraction of $PM_{2.5}$ that infiltrates indoors (F_{inf}) is impacted by temperature (as temperature affects behavior such as window opening and heat and air conditioning use). The temperature used when calculating F_{inf} is based on the two-week average temperature observed at a central monitor in each study area. A 'warm season' model is applied when the average temperature exceed 18 degrees Celsius, and the "summer" time-location patterns are used to calculate the percent of time spent indoors during a typical week. The infiltration model was developed by Ryan Allen at Simon Fraser University[15]. This is a regression model based on MESA Air monitoring data and Air Questionnaire information. Each two-week $PM_{2.5}$ prediction is multiplied by the infiltration fraction and the percent of time spent indoors and this is added to the $PM_{2.5}$ prediction multiplied by the percent of time spent outdoors. These two-week individual-level exposures can be aggregated up to any time scale desired.

1.10.10 K-means

In order to assign exposure to multiple pollutants simultaneously, a clustering method was developed on the national scale. Twenty-two components of $PM_{2.5}$ were used to define 7 component profiles, and predicted cluster membership was assigned based on geographic covariates and proximity to monitoring locations with cluster membership assigned based on measured component profile.[16]

1.10.11 ACT-Specific PM2.5 Likelihood Model Predictions

Predictions were obtained using methods similar to those utilized in MESA-Air (described briefly in Section 1.12.1 above) following the operational details of the hierarchical spatiotemporal model in Keller at al. The model was developed using geographical covariates and $PM_{2.5}$ monitoring data from government monitors and supplemental monitoring campaigns in the Puget Sound, WA region. Government monitoring data include federal reference method (FRM) data from the EPA's Air Quality System (AQS) database, tapered element oscillating microbalance (TEOM) monitors, a federal equivalency method (FEM), and nephelometer monitoring data from the Puget Sound Clean Air Agency (PSCAA). The historical nephelometer data was calibrated with co-located FRM data, available at certain non-industrial nephelometer sites starting around 1999 when FRM monitors became available. Additional monitoring campaigns include the PANEL study, DEEDS study, and remote air data (RAD) monitoring campaign. After covariate pre-processing based on the recommendations in Keller et al., core model fitting was performed using SpatioTemporal, an R package available on CRAN. Predictions cover the period 02/08/1978 – 07/09/2021. However, due to limited monitoring data in the 1980's and 1990's, the quality of model predictions may be a function of time, and less reliable for the 1980's/1990's. Predictions for epidemiological analysis in the ACT cohort should be obtained from KPRI.

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[15] Allen RW, Adar SD, Avol E, Cohen M, Curl CL, et al. 2012 Modeling the Residential Infiltration of Outdoor $PM_{2.5}$ in the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). Environ Health Perspect doi:10.1289/ehp.1104447

[16] Keller J.P., Drton M., Larson T., Kaufman J.D., Sandler D.P., Szpiro A.A. Covariate-adaptive clustering of exposures for air pollution epidemiology cohorts. Ann. Appl. Stat. 2017;11:93–113. doi: 10.1214/16-AOAS992.

1.10.12 SPIROMICS Indoor Exposure Modeling Predictions: Nicotine, NO_2, NO_X, $PM_{2.5}$

Predictions from indoor exposure models are available for 1,579 SPIROMICS participants in seven cities. The predictions are available for two-week periods generated at one-week intervals. The availability of predictions depends on the availability of participants' answers to the Home Information Questionnaire (HIQ) for the address(es) at which they reside, their smoking habits as reported in the Respiratory Disease and Smoke Exposure Questionnaire (RDS), and availability of outdoor pollutant estimates at their location.

All of the models contain census block group-level predictors from the 2010 census, namely median family and household income, median housing value, rates of high school attainment, and rates of owner-occupied housing units. However, this data was not available for all block groups. In cases of missing data for any of these from 2010 census data, values compiled from ACS 5-year estimates (2009-2013) were used instead where possible. Dollar amounts from these were adjusted to 2010 levels using consumer price index data from the Bureau of Labor Statistics.

The model for $PM_{2.5}$ includes building age (an item on the HIQ) as a predictor. At the time the HIQ was administered, 139 of the 1,579 participants for whom predictions are available had not reported this information. In order to generate predictions for these cases, building ages were obtained from various commercial and municipal data sources, primarily Zillow and PropertyShark, for 141 locations. More information, including references, is provided in Appendix L.

1.11. Meteorological Data

Meteorological ("met") data (temperature, humidity, wind speed, wind direction, ceiling height, dew point, sea level pressure, station level pressure, and visibility) are downloaded from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data (LCD) data set at https://www.ncei.noaa.gov/data/local-climatological-data/archive. Meteorological data are available nationally for the years 1980 through February 2022. Weather stations are identified by their Weather Bureau Army Navy (WBAN) and Cooperative Station (COOP) identification numbers, with station metadata obtained from the NOAA Integrated Surface Data data set via the rnoaa R package (as NOAA does not publish this metadata as part of the LCD). Data are formatted and uploaded to the EAC database 'as-is'. Documentation for the LCD is available from NOAA here: https://www.ncei.noaa.gov/data/local-climatological-data/doc/LCD_documentation.pdf .

Temperature and dewpoint are reported in degrees Celsius. Relative humidity is reported as a percentage. Wind speed is reported in m/s. Wind direction is reported as an angle, with zero degrees representing a wind blowing from due north. Visibility and ceiling height are reported in meters. Pressure is reported in hectopascals. Visibility was truncated at 16093 m (10 miles) due to a method change at most sites by the year 2001. Ceiling height is extracted from the "sky conditions" variable as the first cloud height listed. Units are converted to meters. Noon visibility is reported alongside noon relative humidity and noon weather conditions. Each variable is averaged by the hour (in cases where multiple observations exist). The noon-time visibility and relative humidity are reported, and then each day's observations are averaged to provide a daily statistic. Completeness criteria are applied separately to each variable, requiring at least 18 observations, 4 of which must occur in the hours of 04:00 to 09:00, and four in the hours of 13:00 to 18:00. The daily prevailing wind was calculated using vector averaging, with calm wind hours considered to be the 0 vector (no direction reported, speed reported as 0-1.5 m/s). Wind speed was marked as missing when no wind direction was reported.

Meteorological data can be provided from the nearest met monitor or from a single station in each MESA Air community (including Riverside, CA; Rockland County, NY; and the metropolitan areas of the six cities). Because the data outside the MESA Air study areas has not been thoroughly reviewed for completeness and data quality issues, we recommend that "nearest met monitor" data be used with caution. For health analysis requests, we will provide the "community met monitor" data as the default.

1.11.1 B-Spline Variables for Temperature, Humidity, and Calendar Time

For studies of the chronic effects of air pollution on outcomes which may show seasonal variability, an alternative to adjusting directly for temperature and humidity is to adjust for b-spline (basis spline) variables. Users should be aware that each spline generates a large number of variables. However, this allows for very fine and flexible control of seasonal variability. We typically distribute these as variables from b-splines with 6 degrees of freedom per year (i.e. 6 variables per year).

2. Exposure Assessment Core Data Request System

2.1 Placement of a Request

Data requestors are strongly encouraged to complete a Statistical Analysis Plan before requesting data from the EAC. A template for a Statistical Analysis Plan is included in Appendix A. Once a data requestor has a clear idea of the data that he or she will need, that person should submit a data request by filling out the form at https://redcap.iths.org/surveys/?s=CTD7D9HYFKKDE9WM

Instructions are provided within the form. Please contact Amanda Gassett at agassett@uw.edu with questions or feedback. Analysts that are not certain what data to request are encouraged to consult with a member of the EAC data team.

Data requests will be tracked by the project manager and within the database. The Q:\ drive will contain a directory for data requests, and a subdirectory for each request with the output from the original electronic request and the queries used to generate the datasets.

2.2 Maps of Participant-Identifying Information

In some cases, data analysts may desire to include a map of participant locations or exposure modeling predictions in their papers or presentations. It is important to remember that participants' residential locations are considered participant-identifying information and are protected in accordance with the DMDA. Any maps that will be displayed publically or viewed by anyone (including the analyst) who has not read and signed the DMDA must have participant locations jittered so that the actual residential locations are not identified. Other data may be included on the maps as desired. The outline of the desired map can be described in the final text box in the electronic data request form.

2.3 Multiple Users of Requested Data, or Accessing an Existing Request

In some cases, multiple analysts will be working with the same data and the same datasets. Data users are discouraged from sharing data amongst themselves. Data security issues are raised when participant identifying information is transmitted between users, and the EAC prefers to control the transmission of data for the protection of participant data. Furthermore, all data issued by the EAC is subject to caveats, corrections, and updates. The EAC can only ensure that analysts receive the appropriate communications related to the datasets that they are using if the EAC can track which analysts are using which datasets for which projects. Data users are encouraged to contact the EAC if they wish to use existing datasets. In most cases, these requests can be filled with very little delay.

2.4 Fulfillment of a Request

The electronic data request tool generates a report of the request and transmits it to the project manager. As soon as the project manager reads the request, she will send the data requestor a confirmation email with a summary of the data that the EAC data team expects to provide. The original request will be assigned an identification number and attached as a pdf. All members of the EAC data team will receive a carbon copy of this message. The project manager will bring the request to the EAC data team meeting. The details of the request are discussed in the meeting, and the project manager will email the requestor with any clarifying questions.

Data requestors will receive a notification from the QA Officer when the request is complete. The notification will contain a summary of the data that was requested, a brief description of each file produced that includes the number of records that the files contain, and any caveats or additional information that the data team deems necessary. The data requestor should retrieve and review the datasets promptly, and notify the data team of any problems. If no problems are noted, the data requestor should send email confirmation to the project manager or QA Officer that the request can be closed.

Requests will not be updated automatically when new database versions are released, but users will be notified when a new version of the data is available. Data users whose analyses are still in progress should contact the EAC for updates.

Table 25. Summary of data request file locations

Type of File	Type of Data User	File Location	Storage Timeframe
Final, contains participant locations	Final user, without access to MAIDS	Transmitted by email as a password-protected zipped file	Emails should be deleted as soon as possible
Final, no participant locations	Final user, without access to MAIDS	Transmitted by email as a zipped file	Emails should be deleted as soon as possible
Final, contains participant locations	Final user, with MAIDS access	M:/MAIDS/Monitoring Database/Active Data Request - sensitive /<request>/ <filenames>	7 days
Final, no participant locations	Final user, without MAIDS access	M:/MAIDS/Active Data Request - Non sensitive /<request>/ <filenames>	7 days
Interim	EAC data team member	Q:/eac_database/requests/<request>	Indefinite

2.4.1 Data Request Fulfillment: Work Flow Details for Internal Users

Roles for each data request are established in the EAC data team meeting. Once a request is confirmed, one member will be responsible for writing the SQL queries to extract, compile, and process the data into the requested format. A folder will be generated on Q:/ that will contain a copy of the original request, a copy of the SQL queries that generate the final dataset, and will be a temporary storage space for files related to the request. These folders should be generated from the bash shell using "./make_request.sh <name> <description> <file format>".

The request will be filled using the bash shell script, "fill_request.sh". This script is located at /var/local/QUTE/eac_database/requests, and can be accessed from the bash shell with the command "./fill_request.sh <request_id_number>". This script runs the queries to generate datasets, creates a file of 'metadata' which contains the meanings of column names, and creates a record in the request table. This table, housed inside the database, logs the name of the requestor, the date the request was filled, and the query used to fill the request.

A different member of the EAC data team will check the requested datasets for completeness and correctness. Once the dataset generator notifies this person that the datasets are ready for the QA check, the QA auditor will perform their inspection and transfer the files to the appropriate location on

the server. The QA auditor will notify the project manager and QA officer that the request is complete, and the QA officer will notify the data requestor. Once the data requestor expresses satisfaction with the data product, the request can be closed.

Appendices

A. Statistical Analysis Plan (SAP)

Analysis Plan

Working Title:

Overview/Purpose:

General Scientific Question(s):

Specific Scientific Question(s) (e.g. hypotheses):

Outcomes of Interest:

Predictors of Interest:

Potential Confounders or Adjustment Variables:

Other Data Specifics (e.g. time period, subgroup):

Data request (date, number):

Type of Analysis:	Hypothesis testing	Estimation
	Hypothesis screening	Modeling
	Hypothesis generating/exploratory	Method evaluation
	Descriptive	

Analysis Approach and Special Issues:

List of Tables: (or note location of draft tables)

Plan of Action:

Responsibilities and deadlines:

- Paper outline
- Initial analyses
- Introduction
- Methods
- Results
- Discussion
- Tables and Figures
- Follow up analyses
- Final Draft

Names and roles (authors, co-authors, Data Core staff):

Revision History:

B. List of Acronyms and Abbreviations

CAP – Criteria Air Pollutant
CC – Coordinating Center
C-CAR – Center for Clean Air Research
COOP – Cooperative Station
CRAN – Comprehensive R Archive Network
DMDA – Data and Materials Distribution Agreement
EAC – Exposure Assessment Core
EC/OC – Elemental carbon and organic carbon
FIPS – Federal Information Processing Standards
FRM – Federal Reference Method
GIS – Geographic Information System
HAP – Hazardous Air Pollutant
HEI – Health Effects Institute
IMPROVE – Interagency Monitoring of Protected Visual Environments
LAC – Light Absorption Coefficient
LOD – Limit of Detection
MAIDS – MESA Air Intermediate Data Server
MESA – Multi-Ethnic Study of Atherosclerosis
$\mu g/m^3$ – micrograms per cubic meter
NAAQS – National Ambient Air Quality Standards
NEI – National Emissions Inventory
NDVI – Normalized Difference Vegetation Index
NIST – National Institute of Standards and Technology
NO – Nitrogen oxide
NOAA – National Oceanic and Atmospheric Administration
NO_2 – Nitrogen dioxide
NO_X – Oxides of nitrogen, including NO_2 and NO
NPACT – National Particle Components Toxicity
O_3 – Ozone
PM – Particulate matter
$PM_{2.5}$ – Particulate matter <= 2.5 µg in diameter
PM_{10} – Particulate matter <= 10 µg in diameter
POC – Parameter Occurrence Code
ppm – parts per million
ppb – parts per billion
QA – Quality Assurance
QC – Quality Control
S - Sulfur
SAP – Statistical Analysis Plan
Se - Selenium
Si - Silicon
SOP – Standard Operating Procedure
SO_2 – Sulfur dioxide
SPCS – State Plane Coordinate System
STN – Speciation Trends Network
VOC – Volatile Organic Compound
XRF – X-ray fluorescence
WBAN – Weather Bureau Army Navy
WHI - OS – Women's Health Initiative - Observational Study

C. Referenced Documents and Code Locations

Referenced Documents

Description	Directory	Filename
Quality Assurance Project Plan (MESA Air)	M:\MAIDS\QA\QAPP\	QAPP_040709.doc
Final QA/QC Report (MESA Air)	M:\MAIDS\QA\QA report for ESAC\	QAQC_Committee_Report_ 042310.doc
Metadata document	M:\MAIDS\Documentation\GIS\Meta data	Metadata_08042009.doc
Field SOPs	M:\MAIDS\QA\SOPs\Field\ Final\ Current SOPs\PDFs	All documents in directory
Lab SOPs	M:\MAIDS\QA\SOPs\Labs\ Final\PDFs	All documents in directory
Documentation of MESA Air Implementation of CALINE3QHR Model	CALINEDoc2.doc	Subversion repository, ExposureModel\CALINE\
Monitor Issue Log	M:\MAIDS\QA\AQS_QA	Monitor_Issue_Log.xls
QA/QC Report (SPIROMICS Air)	P:\QA\QA_report	QAQC_report_14July16.docx (in progress)
QA/QC Report (CCAR)	W:\UW CCAR\Project 1-5, Cores Folders\Project 5\QC\QAQC_report	
QMP (CCAR)	W:\UW CCAR\QA QC	Quality Management Plan
QA/QC Report (Coarse)		

Useful scripts and codefiles

Purpose	Filename	Language	Directory
Parses pump files for TSI Sidepack 530 pumps	get_pump_data.sas	SAS	H:\ My Documents\sas_code
Reads and processes HOBO files for indoor temperature and relative humidity	get_hobo_data.sas	SAS	H:\ My Documents\sas_code
Removes duplicate road segments from TeleAtlas shapefiles	cat_and_dedup_roads.py	Python	H:\GIS\pycode\mesa\
Calculates covariates for point locations	covar.py	Python	H:\GIS\pycode\mesa\
Parses AQS 'input transaction' formatted files for monitors	ReadAQS_Monitors.sas	SAS	M:\MAIDS\ EPA monitoring\Programs
Parses AQS concentration files	ReadAQS_NO2.sas ReadAQS_Nox.sas ReadAQS_PM25.sas	SAS	Subversion repository, Data_Processing_Codes\ MesaAQS_Raw directory
Read in and combine data tables in the NEI database	Read Sources.sas	SAS	M:\MAIDS\Emissions Data\Programs\
Parses and formats raw temperature and humidity data	ReadMet.sas	SAS	M:\MAIDS\MeteorologicalData\ Programs
Nearest Monitor Calculation	nearest.R	R	Subversion repository, ExposureModel\ SimpleModels\
Updates metadata table	metadata_tbl.py	Python	Q:\eac_database\code
Creates request folder	make_request.sh	Bash	Q:\eac_database\requests
Generates data request datasets and metadata	fill_request.sh	Bash	Q:\eac_database\requests

Locations of raw monitoring data

Contents	Filename	Directory
Field log data	MESA_Samples_V1_2008_10_10.mdb	M:\MAIDS\COC
Teflon mass measurements	MESA_Air_FilterMassEntry_v1_2.mdb	M:\MAIDS\GravLACAnalysis\database
Teflon LAC measurements	MESA_Air_Reflectometry_v1_1.mdb	M:\MAIDS\GravLACAnalysis\database
Ion Chromatography measurements for Ogawas (NO_2, SO_2, and O_3)	IC<YYYMMDD_##>.xls	M:\MAIDS\AnalyticLab\Edited IC Data for Import Jim
Ultraviolet Spectroscopy (For NO_X)	UV<YYYMMDD_##>.xls	M:\MAIDS\AnalyticLab \Edited UV Data for Import Jim
Infiltration questionnaire	InfiltrationObservaton_v_1_09_10_08.mdb	M:\MAIDS\Field\Databases
Time Activity Diary for personal sampling	TimeActivity_v_3.0.mdb	M:\MAIDS\Field\Databases
Chain of Custody (sample handling and shipping history)	MESA_Samples_V1_2008_10_10.mdb	M:\MAIDS\COC

D. Suggested Citations

Data Description	Suggested Citation
Airport and point source emission volumes[a]	USEPA, Emission Inventory Group, 2002 National Emissions Inventory Database [digital data set] (2006). U.S. Environmental Protection Agency: Washington, DC. Available FTP: http://www.epa.gov/ttn/chief/net/2002inventory.html [accessed Aug 2008].
Road, railroad, railyard, and airport locations, coastlines	TeleAtlas, TeleAtlas Dynamap 2000 [CD_ROM] (2000). TeleAtlas, Lebanon, NH.
Population density	U.S. Department of Commerce, Census Bureau, TIGER/Line Shapefiles (2001). U.S. Department of Commerce, Census Bureau: Washington, DC. Available FTP: http://arcdata.esri.com/data/tiger2000/tiger_download.cfm, redistributed by TeleAtlas Dynamap 2000 [CD_ROM] (2000). TeleAtlas, Lebanon, NH.
Land use	Price, C.V., Nakagaki, N., Hitt, K.J., and Clawges, R.C., Enhanced Historical Land-Use and Land-Cover Data Sets of the U.S. Geological Survey, U.S. Geological Survey Digital Data Series 240 [digital data set] (2006). Available: http://pubs.usgs.gov/ds/2006/240 [accessed Jun 2009].
Port locations and characteristics[b]	National Imagery and Mapping Agency (NIMA), Ports of the Wider Caribbean, from NIMA World Port Index (2002). Distributed by the World Resources Institute: Washington, DC. Available FTP: http://164.214.12.145/pubs/pubs_j_wpi_sections.html [accessed Jun 2009].
EPA AQS data	USEPA, Air Quality System Data: Query AQS Data [digital data set] (2011). U.S. Environmental Protection Agency: Washington, DC. Available: http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm [accessed June 2013].
Meteorological data	NOAA, Local Climatological Data & Integrated Surface Dataset [digital data set] (2022). National Centers for Environmental Information: Asheville, NC. Available: https://www.ncei.noaa.gov/data/local-climatological-data/archive/ [accessed March 2022].
NDVI[a]	Carroll, M.L., C.M. DiMiceli, R.A. Sohlberg, and J.R.G. Townshend, 250m MODIS Normalized Difference Vegetation Index [digital data set] (2008). University of Maryland, College Park, Maryland. All available days, 2006. Available: http://glcf.umiacs.umd.edu/data/ndvi/.
NYCCAS Data	The New York City Department of Health and Mental Hygiene, Queens College Center for the Biology of Natural Systems, and Zev Ross Spatial Analysis.
U.S. Census Data	Census 2000 Summary File 3—United States/ prepared by the U.S. Census Bureau, 2002.
U.S. Truck Routes	National Transportation Atlas Database [digital data set] (2009). Bureau of Transportation Statistics: Washington, DC. Available: http://www.bts.gov/publications/national_transportation_atlas_database.
NY Bus Routes	Quodomine, R. 2013. Personal communication (email with E. Spalt, University of Washington). New York Department of Transportation, Albany, NY.
Impervious Surface	NLCD 2006 Percent Developed Imperviousness [digital data set] (2006). Multi-Resolution Land Characteristics Consortium: Sioux Falls, SD. Available: http://ims.cr.usgs.gov/webappcontent/mrlc/nlcd2006_downloads.php.

Suggested citations, continued

MESA Air Monitoring Method	Cohen, Martin A., Adar, Sara D., Allen, Ryan W., Avol, Edward, Curl, Cynthia L., Gould, Timothy, Hardie, David, Ho, Anne, Kinney, Patrick, Larson, Timothy V., Sampson, Paul, Sheppard, Lianne, Stukovsky, Karen D., Swan, Susan S., Liu, L.-J. Sally, Kaufman, Joel D., Approach to Estimating Participant Pollutant Exposures in the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). Environmental Science & Technology 2009, 43 (13), 4687-4693.

[a] This link no longer works or this exact file is no longer available online. Please refer to table 10 for current links.

[b] This file is no longer available online, and the National Imagery and Mapping Agency no longer exists. The current version (the Twentieth Edition) is produced by the National Geospatial Intelligence Agency.

E. Known Data Quality Issues

Issue	Extent of Data Affected	Expected Resolution
Overlapping polygons in land use shapefiles (>100% land use totals)	Locations along the coast of NC (primarily Sisters and WHI locations)	Manually fix shapefiles
Because the Oregon truck routes were determined by a different method than the rest of the US, truck route line lengths are doubled along A1 highways	Locations near A1 highways in Oregon (i.e. Sisters, WHI, AQS monitors)	Manually fix shapefiles
Distance to city hall calculations not correctly implemented in psql		

F. Quick Reference for Averaged Exposure Variable Names

Analysts may consider exposure periods ranging from a single day or week prior to an exam up to a number of years. Some may consider multiple exposure periods. Standard naming conventions help distinguish these different exposure periods quickly and easily. The set formats for these variable names are:

<pollutant>_<model>_<t1>_<t2>_<interval>_<reference>_<weighting>
<pollutant>_<model>_<e1>_<e2>_<rounding>_<reference>_<weighting>
<pollutant>_<model>_<yymm1>_<yymm2>_<weighting>
<pollutant>_<model>_year_<year>_<weighting>
MET_<meteorology>_<t1>_<t2>_<interval>_<reference>_<weighting>

A table of the options that appear between brackets is included below. Characters without brackets appear as literals.

Pollutants include all of the gases, elements, and PM sizes that have been mentioned throughout this document. Models include both very sophisticated spatio-temporal models as well as 'simple' models such as 'nearest monitor' for $PM_{2.5}$. The numbers t1 and t2 indicate the span of the averaging period, while 'interval' indicates the units of time to which t1 and t2 refer. Much of time, analysts are

interested in a particular event, such as an exam, a stroke, or a diagnosis of disease. This is the reference point. Finally, some analysts will need the exposure averaged or weighted by the locations where participants actually lived. Others will need the average at a particular location over the entire time period, regardless of whether the participant lived at that location during the entire time period. Meteorological measurements can be averaged over similar time frames and will have similar names to indicate the averaging period. However, 'weighting' will not be indicated, as there is only one meteorological time series in each study area.

Table of parameter options

Pattern Code	Description	Values	Meaning
pollutant	Pollutant of interest	PM25, PM10, Si, S, EC, OC, NOx, NO2, O3, etc.	
model	Pollution model type	prag lik nat acute near	pragmatic likelihood national (long term) acute regional time series nearest monitor
meteorology	Meteorological variable	temp rh windspd winddir	temperature humidity wind speed wind direction
t1, t2	Timepoints that define beginning and end of the exposure averaging period	Integers from 0 – 99 "a" followed by an integer 1-99	Intervals before reference Intervals after reference
e1, e2	Exam numbers	integer 1-6	Exam numbers between which average is calculated
rounding	Whether time between exams is rounded to nearest whole year	rnd trc N/A	Round (nearest whole) Truncate (round down) Exact time
interval	Units of time	dy wk qt yr	Day week quarter year
reference	Reference point, or event that defines what the exposure is prior to	enrol event exam ct us mri	Enrollment event (MI, stroke, diagnosis) clinic exam
weighting	Indicates whether the average is weighted over all addresses at which participants lived during the exposure period	wght stat wsp statsp	weighted by all addresses static, usually refers to 'at exam' address weighted, spatial-only model static, spatial-only model
yymm1, yymm2	Fixed endpoints of exposure period	0001 – 1112	two-digit year and two-digit month (beginning of month in endpoint 1 through end of month in endpoint 2)

I. Performance Statistics for Exposure Models

Table 26. Number of monitors and cross-validated measures of predictive accuracy for exposure models of NO_2, NO_x, $PM_{2.5}$, and O_3 for SPIROMICS Air. Leave-one-out cross-validation was used for AQS and fixed sites and ten-fold cross-validation was used for home sites.

City	Modeling region radius (km)	Number of monitors				AQS and fixed sites		Home sites	
		A	F	H/O	S	R^2_{reg}	R^2_{mse}	R^2_{reg}	R^2_{mse}
NO_x									
Baltimore	75	8	4	115	194	0.90	0.88	0.87	0.90
Los Angeles	90	28	7	186	263	0.85	0.85	0.89	0.90
San Francisco	75	15	0	32	100	0.73	0.70	0.71	0.82
New York	90	12	3	144	258	0.80	0.66	0.76	0.52
Salt Lake City	90	6	0	35	104	0.78	0.75	0.81	0.90
Ann Arbor	90	4	0	31	102	0.70	0.52	0.57	0.90
Winston-Salem	150	3	4	201	216	0.79	0.71	0.61	0.61
NO_2									
Baltimore	75	11	4	115	194	0.82	0.82	0.90	0.92
New York	90	18	3	145	258	0.87	0.87	0.83	0.79
San Francisco	75	21	0	31	99	0.88	0.87	0.91	0.92
Los Angeles	90	29	7	186	265	0.88	0.87	0.88	0.92
Salt Lake City	90	6	0	35	104	0.80	0.75	0.88	0.95
Winston-Salem	150	2	4	207	216	0.63	0.54	0.73	0.82
Ann Arbor	90	5	0	31	102	0.67	0.61	0.75	0.93
O_3									
Baltimore	75	25	0	88	91	0.93	0.90	0.79	0.85
New York	90	27	0	116	98	0.87	0.81	0.78	0.82
San Francisco	75	31	0	32	99	0.85	0.85	0.83	0.64
Los Angeles	90	33	0	182	95	0.82	0.71	0.78	0.90
Salt Lake City	175	21	0	34	104	0.82	0.82	0.80	0.84
Winston-Salem	200	49	0	191	95	0.68	0.68	0.68	0.55
Ann Arbor	200	34	0	30	102	0.85	0.84	0.60	0.82
$PM_{2.5}$									
Baltimore	150	34	5	108	0	0.89	0.88	0.92	0.93
New York	150	90	2	105	0	0.87	0.82	0.44	0.58
San Francisco	150	23	0	32	0	0.88	0.86	0.64	0.67
Los Angeles	100	25	2	88	0	0.86	0.83	0.71	0.89
Salt Lake City	120	21	0	35	0	0.93	0.89	0.49	0.71
Winston-Salem	175	52	4	121	0	0.89	0.89	0.91	0.88
Ann Arbor	175	46	0	31	0	0.88	0.88	0.38	0.29

A – AQS, F – Fixed, H/O – Home outdoor, S – Snapshot, R^2_{reg} – Regression-based R-squared, R^2_{mse} – MSE-based R-squared

Table 29. Number of monitors and cross-validated measures of long-term predictive accuracy for exposure models of NO_2, NO_x, $PM_{2.5}$, and O_3 for the "omnibus" models combining MESA Air and SPIROMICS Air. Leave-one-out cross-validation was used for AQS and fixed sites and ten-fold cross-validation was used for home sites.

City	Modeling region radius (km)	Number of monitors				AQS and fixed sites		Home sites	
		A	F	H/O	C/S	R^2_{reg}	R^2_{mse}	R^2_{reg}	R^2_{mse}
NO_x									
Baltimore	75	8	4	115	237	0.76	0.75	0.88	0.88
Los Angeles	125	31	7	210	372	0.91	0.91	0.85	0.84
San Francisco	120	20	0	34	100	0.64	0.56	0.69	0.56
New York	75	16	8	294	258	0.73	0.69	0.67	0.68
Salt Lake City	120	7	0	35	104	0.76	0.70	0.75	0.93
Ann Arbor	220	7	0	31	102	0.58	0.42	0.42	0.37
Winston-Salem	150	3	4	208	256	0.85	0.66	0.79	0.79
Chicago	75	9	5	113	129	0.56	0.61	0.75	0.76
St. Paul	75	5	4	130	144	0.89	0.85	0.86	0.86
NO_2									
Baltimore	75	12	4	115	237	0.86	0.87	0.85	0.85
New York	75	19	8	295	258	0.87	0.88	0.75	0.75
San Francisco	75	21	0	32	100	0.76	0.77	0.84	0.83
Los Angeles	125	39	7	212	374	0.92	0.92	0.86	0.85
Salt Lake City	120	7	0	35	104	0.43	0.64	0.73	0.68
Winston-Salem	150	3	4	210	258	0.76	0.67	0.73	0.72
Ann Arbor	175	5	0	31	102	0.74	0.81	0.56	0.59
Chicago	75	9	5	112	129	0.73	0.68	0.77	0.77
St. Paul	75	5	4	132	150	0.86	0.83	0.88	0.88
O_3									
Baltimore	75	27	0	88	134	0.77	0.76	0.76	0.74
New York	90	27	5	266	101	0.68	0.61	0.73	0.73
San Francisco	75	26	0	32	101	0.85	0.85	0.83	0.64
Los Angeles	125	45	0	207	138	0.81	0.72	0.75	0.74
Salt Lake City	320	35	0	34	104	0.64	0.66	0.69	0.62
Winston-Salem	300	82	0	187	138	0.68	0.68	0.64	0.58
Ann Arbor	230	52	0	31	102	0.55	0.51	0.60	0.82
Chicago	125	45	0	79	0	0.76	0.73	0.79	0.78
St. Paul	220	15	0	95	43	0.46	0.52	0.82	0.80
$PM_{2.5}$									
Baltimore	75	27	4	108	0	0.89	0.90	0.94	0.93
New York	75	42	8	274	0	0.90	0.86	0.60	0.60
San Francisco	75	11	0	30	0	0.88	0.87	0.61	0.63
Los Angeles	125	29	7	136	0	0.85	0.85	0.85	0.85
Salt Lake City	120	21	0	35	0	0.64	0.63	0.83	0.83
Winston-Salem	150	30	4	142	0	0.94	0.94	0.95	0.95
Ann Arbor	175	28	0	31	0	0.70	0.66	0.14	0.09
Chicago	75	32	5	135	0	0.87	0.87	0.83	0.83
St. Paul	75	17	3	125	0	0.33	0.18	0.86	0.84

A – AQS, F – Fixed, H/O – Home outdoor, C/S – Community Snapshot, R^2_{reg} – Regression-based R-squared, R^2_{mse} – MSE-based R-squared

Table 27. 10-fold cross-validated R^2 and RMSE by year for national **NO_2** model. All metrics are on the square root scale (sqrt(ppb)).

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
R^2	0.83	0.86	0.86	0.87	0.89	0.85	0.86	0.86	0.87	0.87	0.85	0.86
RMSE	0.54	0.48	0.46	0.44	0.40	0.46	0.42	0.42	0.40	0.40	0.40	0.40
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
R^2	0.88	0.89	0.85	0.85	0.85	0.82	0.83	0.84	0.82	0.85	0.79	0.83
RMSE	0.39	0.35	0.37	0.37	0.39	0.41	0.39	0.39	0.39	0.36	0.41	0.34
Year	**2014**	**2015**										
R^2	0.83	0.83										
RMSE	0.35	0.35										

Table 28. 10-fold cross-validated R^2 and RMSE by year for national satellite-based **NO_2** model. All metrics are on the square root scale (sqrt(ppb)).

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
R^2												
RMSE												
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
R^2												0.84
RMSE												0.34
Year	**2014**	**2015**										
R^2	0.85	0.84										
RMSE	0.33	0.34										

Table 29**.** 10-fold cross-validated R^2 by year for national **PM_{10}** model. All metrics are on the square root scale (sqrt(μg/m^3)).

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
R^2	0.58	0.62	0.59	0.63	0.54	0.58	0.51	0.52	0.47	0.53	0.53	0.51
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**			
R^2	0.55	0.52	0.49	0.50	0.44	0.42	0.45	0.61	0.40			

Table 30**.** 10-fold cross-validated R^2 by year for national **$PM_{2.5}$** model. All metrics are on the square root scale (sqrt(μg/m^3)). Year 2000 published in Sampson et al, Atmospheric Env, 2013.[17]

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
R^2	0.88	0.88	0.89	0.88	0.87	0.88	0.91	0.88	0.89	0.85	0.86	0.77	0.73
Year	**2012**	**2013**	**2014**	**2015**									
R2	0.82	0.82	0.83	0.84									
RMSE	0.18	0.19	0.19	0.17									

[17] Paul David Sampson, Mark Richards, Adam A Szpiro, Silas Bergen, Sheppard Lianne, Timothy V Larson, Joel D Kaufman, 2013. A Regionalized National Universal Kriging Model using Partial Least Squares Regression for Estimating Annual PM2.5 Concentrations in Epidemiology. Atmospheric Environment 75, 383-392.

Table 31. Cross-validated R^2 and RMSE for EC, OC, Si, and S PM2.5 Components. All metrics are on the square root scale. Published in Bergen et al, EHP 2013.[18]

	EC	**OC**	**Si**	**S**
R^2	0.79	0.60	0.36	0.63
RMSE	0.11	0.22	0.10	0.13

Table 32. Cross-validation statistics of the historical $PM_{2.5}$ models for 1999-2010 by year and region.

Estimated trend		Linear trend from FRM/IMPROVE[a] $PM_{2.5}$	
Cross-validation statistics		R^2	MSE
Year/region	N[b]		
All[c]	1,460 (10,800)	0.87	2.08
1999	523	0.86	3.29
2000	865	0.85	2.38
2001	988	0.86	2.32
2002	1,054	0.84	2.39
2003	969	0.85	2.13
2004	980	0.86	1.99
2005	940	0.88	2.08
2006	898	0.86	1.87
2007	937	0.86	1.85
2008	902	0.82	1.82
2009	884	0.80	1.61
2010	860	0.83	1.63
East[c]	1,056 (7,956)	0.86	1.19
Mountain West[c]	239 (1,594)	0.59	3.84
West Coast[c]	165 (1,250)	0.84	5.50

a. FRM = Federal Reference Method; IMPROVE = Interagency Monitoring of Protected Visual Environment; CASTNet = Clean Air Status and Trends Network; WBAN = Weather-Bureau-Army-Navy
b. Number of sites (Number of observations when different from the number of sites)
c. Annual averages from 1999 through 2010

[18] Bergen S, Sheppard L, Sampson PD, Kim SY, Richards M, Vedal S, Kaufman JD, Szpiro AA. 2013. A national prediction model for $PM_{2.5}$ component exposures and measurement error–corrected health effect inference. **Environ Health Perspect** 121:1017–1025; http://dx.doi.org/10.1289/ehp.1206010

Table 33. 10-fold cross-validated R^2 on native and model scale for As, Du, Ni, SO4, So2, NO3, V, and Cr. * All components except for Cr were developed using covariates from Rev 5. Cr was built using Rev 4 covariates.

Pollutant	R^2	R^2 (native)	Modeling scale
As	0.84	0.59	log
Cu	0.79	0.26	log
Ni	0.75	0.48	log
SO4	0.91	0.87	sqrt
SO2	0.37	0.32	sqrt
NO3	0.86	0.82	sqrt
V	0.80	0.59	log
Cr*	0.74	0.07	log

Table 34. Model performance (10-fold cross validated R^2 and RMSE) for $PM_{10-2.5}$ mass ($\mu g/m^3$) and species concentrations (ng/m^3) using land use regression (LUR). Table adapted from Zhang et al, Under review at EHP, 2013.[19]

City	CV Measure	Total Mass	Cu	P	Si	Zn
Chicago, IL	**R^2**	0.68	0.65	0.50	0.68	0.73
	RMSE	1.16	2.29	3.88	82.10	10.63
St Paul, MN	**R^2**	0.51	0.86	0.68	0.93	0.40
	RMSE	2.33	0.61	4.14	72.60	4.44
Winston Salem, NC	**R^2**	0.41	0.51	0.76	0.48	0.36
	RMSE	1.09	0.93	3.95	73.10	1.89
All cities	**R^2**	0.47	0.73	0.55	0.43	0.65
	RMSE	1.84	0.00	0.00	0.15	0.01

[19] Zhang K, Larson TV, Gassett A, Szpiro AA, Daviglus M, Burke GL, Kaufman JD, Adar SD. Characterising spatial patterns of airborne coarse particulates (PM10-2.5) mass and chemical components in three cities: the Multi-Ethnic Study of Atherosclerosis. Under review at Environmental Health Perspectives.

Table 35. Leave-one-out cross validation RMSE of $PM_{2.5}$ using "Pragmatic Model" at all sites and at fixed sites on native scale (ug/m3). * N is the number of sites used for modeling. Modified from Table 2 in Sampson et al, Atmostpheric Environment, 2011. [20]

Site	All Sites				MESA Air Fixed Sites			
	N*	Mean	SD	RMSE	N	Mean	SD	RMSE
CA	31	17.84	4.47	2.42	7	20.64	3.04	1.98
IL	51	14.52	1.83	1.32	7	14.59	1.93	1.86
MN	44	10.68	1.49	0.88	3	10.61	0.72	1.05
MD	44	14.90	1.23	1.05	5	15.77	0.90	1.24
NY	48	13.66	1.58	1.21	3	14.70	2.52	1.75
NC	33	14.38	0.90	0.95	4	14.84	0.33	1.02

Table 36. 10-fold cross-validation of National Spatiotemporal PM2.5 Model. These validation statistics are produced automatically as an output of this model. See code for additional details (step4_national_CV.R)

year	MSER2.spatio	REGR2.spatio	RMSE.spatio	MSER2.temp	REGR2.temp	RMSE.temp	n.sites
1999	0.89	0.90	1.533	0.54	0.54	3.492	648
2000	0.87	0.88	1.512	0.55	0.56	3.086	981
2001	0.87	0.88	1.515	0.56	0.57	2.991	1085
2002	0.88	0.88	1.318	0.67	0.67	2.600	1120
2003	0.88	0.88	1.314	0.64	0.64	2.428	1094
2004	0.89	0.89	1.250	0.61	0.61	2.466	1082
2005	0.90	0.90	1.319	0.56	0.57	2.931	1061
2006	0.86	0.86	1.339	0.57	0.57	2.521	1038
2007	0.87	0.87	1.319	0.63	0.63	2.633	1041
2008	0.83	0.84	1.280	0.56	0.56	2.441	1030
2009	0.83	0.83	1.155	0.50	0.51	2.356	1007
2010	0.87	0.88	1.084	0.52	0.52	2.156	959
2011	0.85	0.86	1.085	0.58	0.58	2.209	909
2012	0.78	0.79	1.144	0.48	0.49	2.097	878
2013	0.81	0.81	1.122	0.58	0.59	2.134	855
2014	0.83	0.83	1.117	0.55	0.55	2.128	806
2015	0.81	0.81	1.026	0.59	0.59	2.025	788
2016	0.70	0.71	0.921	0.53	0.53	1.709	610
all yrs	0.89	0.89	1.104	0.64	0.64	2.582	1495

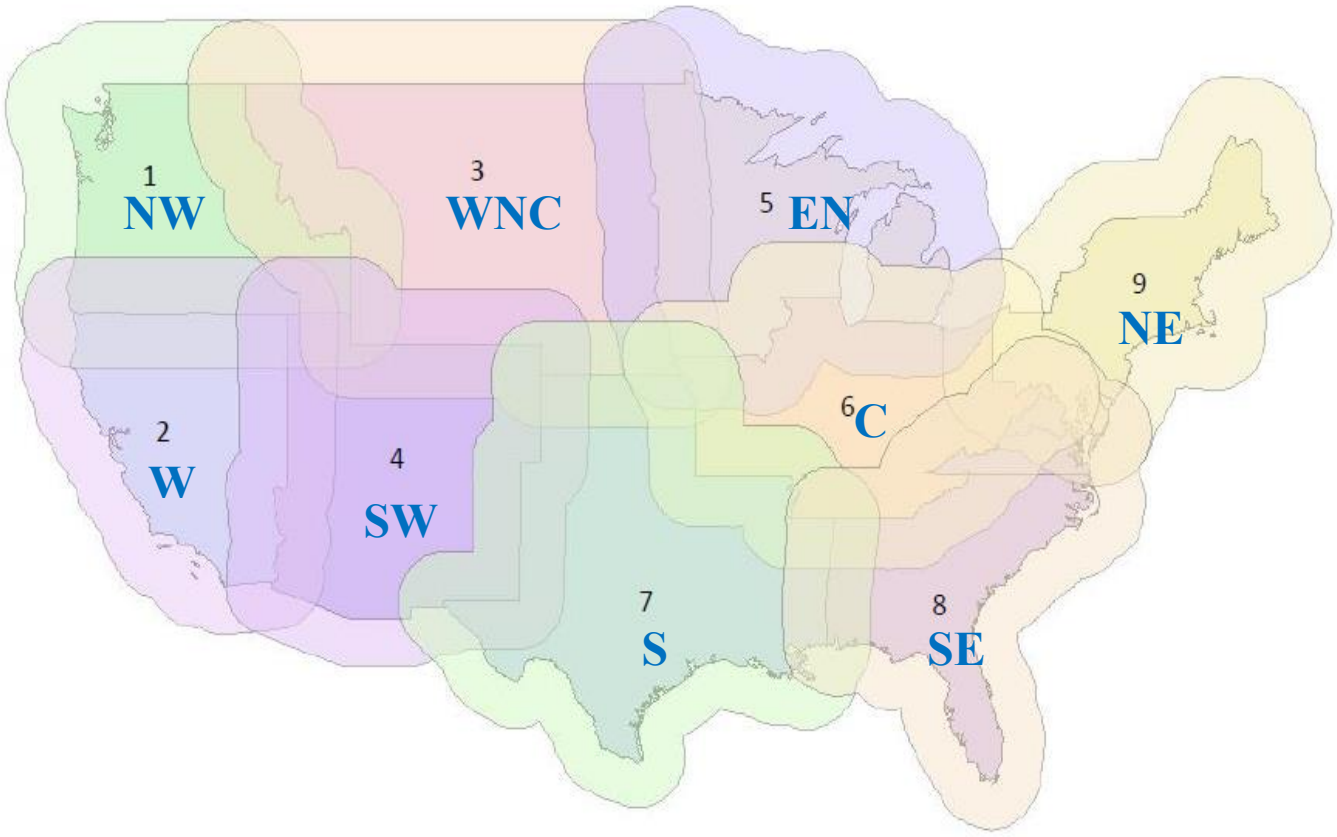
[20] Sampson, P. D., Szpiro, A. A., Sheppard, L., Lindström, J., & Kaufman, J. D. 2011. Pragmatic estimation of a spatio-temporal air quality model with irregular monitoring data. *Atmospheric Environment*, *45*(36), 6593-6606.

Table 37. Cross-validation measures of predictive accuracy for site means at monitoring locations for likelihood-based exposure models of PM2.5 in the Puget Sound. Leave-one-out cross-validation was used for AQS and Historical Nephelometer sites and ten-fold cross-validation was used for RAD monitor sites. R2reg represents the regression R2.

	AQS and Nephelometer Sites			**RAD Monitor Sites**		
Region	**RMSE**	R^2_{CV}	R^2_{reg}	**RMSE**	R^2_{CV}	R^2_{reg}
$PM_{2.5}$						
Puget Sound	1.29	0.87	0.87	0.89	0.78	0.79

J. National Spatiotemporal $PM_{2.5}$ Modeling Regions

Figure. Participant locations and modeling region (left), Monitoring locations (right)



K. Database location tables

Preferred table naming conventions:
For batches of participant locations: <study>_<yyyymmdd>_location_tbl
For

Table 38. Location table names with native id patterns

Table Name	native_id example	Native id pattern	Contents
actb2_location_tbl	ACT1001_0201	<study><ppt_id>_<batch><#>	ACT addresses, batch 2
actb3_location_tbl	ACT1001_0301	<study><ppt_id>_<batch><#>	ACT addresses, batch 3
actb4_location_tbl	ACT1002_0401	<study><ppt_id>_<batch><#>	ACT addreses, batch 4
actsnap_location_tbl	001A	<cluster><position>	ACT snapshot addresses
agency_location_tbl	10010002	<state & county fips><unique>	Air Agency monitoring locations
brfss_location_tbl	98001_0304012022c	<zip>_<id>	BRFSS study locations
ccarc_location_tbl	ccarc_000000	<study>_< id>	CCAR Collaborative study grid points
ccarflightpath_location_tbl	ccarflightpath_1	<study>_< id>	LAX flightpath ogawa monitoring locations
ccarp1_location_tbl	ccarp1a0000001	<study>< id>	CCAR Project 1 Ogawa and mobile monitoring locations
ccarp5_location_tbl	ccarp5_400	<study>_< id>	CCAR Project 5 participant home monitoring locations
cf2_location_tbl	cf2_010010204003000	<study><ppt_id>	Cystic fibrosis locations, batch 2
cf_location_tbl	cf110010077031003	<study><ppt_id>	Cystic fibrosis locations
chsaq_location_tbl	chsaq060370016	<study><ppt_id>	
cohort_act_location_tbl	1001-1	<ppt_id>_<#>	ACT addresses, batch 1
cohort_chs_location_tbl	3000028-1	<ppt_id>_<#>	
cohort_classic_location_tbl	classic3010007-01	<study><ppt_id>-<#>	MESA classic participant locations (Rev 12 or earlier)

cohort_fn_location_tbl	NRFam3110044-01	<study><ppt_id>-<#>	MESA Family & New REcruits participant locations (Rev 12 or earlier)
cohort_ln_gem_location_tbl	GEM110001-01	<study><ppt_id>-<#>	GEMS home locations, from LexisNexis
cohort_omega_location_tbl	omega10007-01	<study><ppt_id>-<#>	Omega participant locations
cohort_sister_hist_location_tbl	H1000010001	H<ppt_id><ind><ind><ind><ind>	Childood and longest-lived sister locations that don't coincide with current
cohort_sister_location_tbl	1000011010	<ppt_id><ind><ind><ind><ind>	Current sister study locations
cohort_sister_two_location_tbl	T6000020011	T<ppt_id>	Two Sister Study locations
cohort_spiro_location_tbl	spiro_A001000-0		Spiromics locations at baseline
cohort_va_location_tbl	va0000	<study><id>	VA study nearest intersections
cohort_whi_location_tbl	whi01000021	<study><unique>	Original WHI locations
consortium_regards_location_tbl	100012_1	<ppt_id>_<#>	REGARDS locations to be used for consortium project
consortium_sister_location_tbl	s1000011010	<study><ppt_id>	Sister Study locations provided recently
dichot_location_tbl	dichot2032		Dichot monitoring locations
fixed_location_tbl	B001		MESA Air fixed sites
gems_location_tbl	gems_110001-1	<study>_<ppt_id>-<#>	GEMS study locations
grid_100m_location_tbl	grid_100m_1	grid_<resolution>_<#>	
grid_50m_location_tbl	CA5_50m_0	<stateplane>_<resolution>_<#>	Fine grid locations in MESA cities
grid_deeds_50m_location_tbl	grid_50m_10	grid_<resolution>_<#>	Fine grid locations covering Duwamish study area
grid_location_tbl	B_0001		1km, 2km, and 500m grid locations coverin g MESA modeling regions
grid_nation_25km_location_tbl	ALE_25km_13451	<stateplane>_<resolution>_<#>	National grid

grid_ps_location_tbl	PS_1000_1	<region>_<resolution>_<#>	Puget Sound grid
hr0287_pa_locations_location_tbl	pghcty001		
ipn_location_tbl	10380003		Locations of the Inhalable Particle Network
ivf_location_tbl	ivf_0005814		IVF study locations
massblocks_location_tbl	250010102062101a001		
mesa_2019_location_tbl	classic3010007-09	<stdy><ppt_id>-<#>	MESA Classic home locations, from 2019 update
met_location_tbl	69007093217		Locations of met stations from NOAA
monitoring_act_location_tbl	ACTV001		ACT volunteer and home monitoring participant locations
monitoring_deeds_location_tbl	1313326		DEEDS monitoring locations
monitoring_mesa_location_tbl	B		MESA Home monitoring locations
monitoring_mesa_pilot_location_tbl	wilton_001		MESA IAr pilot Ogawa monitoring locations
monitoring_norris_location_tbl	norris_A		Ear;y 90's ogawa-like monitoring
monitoring_panel_location_tbl	panel_101		1999 panel-study home monitoring locations
monitoring_rad_location_tbl	ACTV001		Remote Air Data monitoring locations, including MESA Air R56
monitoring_spiro_location_tbl	spiro_A01A	<spiro>_<ciy><site>	SPIROMICS homes monitoring locations
monitoring_yesler_location_tbl	1304757		Yesler Terrace monitoring locations
nhs2_location_tbl	NHS20000001		Nurse's Health Study home locations
nomas_location_tbl	nomas_00001		NOMAS participant locations

nyccas_location_tbl	nyccas10023		New York City Communicaty Air Study monitoring locations
oakmonitors_location_tbl	oakmonitor_00002A		Oakland monitoring locations (external project, no monitoring data in database)
oakroads_location_tbl	oakroad_000001		Oakland on-road locations
presto_location_tbl	10201-01		PRESTO residential locations
pscaa_location_tbl	AB		Pugest Sound Clean Air Agency monitoring locations, may not be included in Agency dataset
psid2015_location_tbl	psid2015_010010201002023c		PSID
psid_location_tbl	010010201002023C		
ros_location_tbl	ros_1		Religious Orders Study locations
rush_location_tbl	rush_1_1		
sister_test_location_tbl	s2041370100		?
spiro_fu_location_tbl	spiro0001-1		
tract2000_location_tbl	06025010100c		
tract2010_location_tbl	1E+09		
whicap_location_tbl	whicap_000001		
whi_2019_location_tbl	whi01000017-01		

M. SPIROMICS Indoor Exposure Modeling Predictions

Table 39. Indoor exposure modeling participants, dates, and cities

City		Nicotine	NO_2	NO_x	$PM_{2.5}$
Ann Arbor	*n*	244	238	238	244
	dates	12/30/1998 12/21/2016	3/29/2000 11/2/2016	1/2/2002 11/2/2016	12/30/1998 11/2/2016
Baltimore	*n*	191	186	186	187
	dates	12/30/1998 12/28/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016
Los Angeles	*n*	171	169	169	171
	dates	1/6/1999 12/21/2016	1/6/1999 12/21/2016	1/6/1999 12/21/2016	1/6/1999 12/21/2016
New York	*n*	295	252	252	290
	dates	1/6/1999 12/21/2016	1/6/1999 9/28/2016	1/6/1999 9/28/2016	1/6/1999 9/28/2016
Salt Lake City	*n*	262	262	262	262
	dates	12/30/1998 12/28/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016
San Francisco	*n*	212	205	205	210
	dates	1/6/1999 12/21/2016	1/6/1999 8/31/2016	12/27/2006 8/31/2016	1/6/1999 8/31/2016
Winston-Salem	*n*	205	194	194	204
	dates	12/30/1998 12/28/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016	12/30/1998 11/30/2016

Table 40. Census data filled via ACS 5-year estimates

Variable	Missing blockgroups	Filled blockgroups
Median family income	11	6
Median household income	5	1
% high school attainment	1	0
% owner-occupied housing units	2	0
Median housing value	118	94

References for Census data:
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U.S. Bureau of Labor Statistics. Consumer Price Index - All Urban Consumers (Current Series). Retrieved from https://download.bls.gov/pub/time.series/cu/

U.S. Census Bureau. Selected housing characteristics, 2009-2013 American Community Survey 5-year estimates. Retrieved from https://data.census.gov/cedsci/table?q=United%20States&tid=ACSDP5Y2018.DP05&hidePreview=false

Table 41. Additional sources for building ages by web domain

Domain	*n*
zillow.com	73
www.propertyshark.com	49
www.apartments.com	6
address.mylife.com	2
www.redfin.com	2
www.trulia.com	2
apartable.com	1
chp-sf.org	1
foundationhousing.com	1
sfplanninggis.org	1
www.appraisalinstitute.org	1
www.city-data.com	1
www.realtor.com	1

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Community Housing Partnership [San Francisco]. 2020. Chp-sf.org. https://chp-sf.org

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National Association of Realtors and Move, Inc. 2020. Realtor.com. https://www.realtor.com

Property Research Partners LLC. 2020. PropertyShark.com. https://www.propertyshark.com

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San Francisco Planning Department. 2020. San Francisco Planning GIS Tools. https://sfplanninggis.org

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