Development of a Fine-Scale, On-Road, Mobile Source Emissions Inventory for the San Francisco Bay Area

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Air Quality Research and Innovative Solutions

Outline

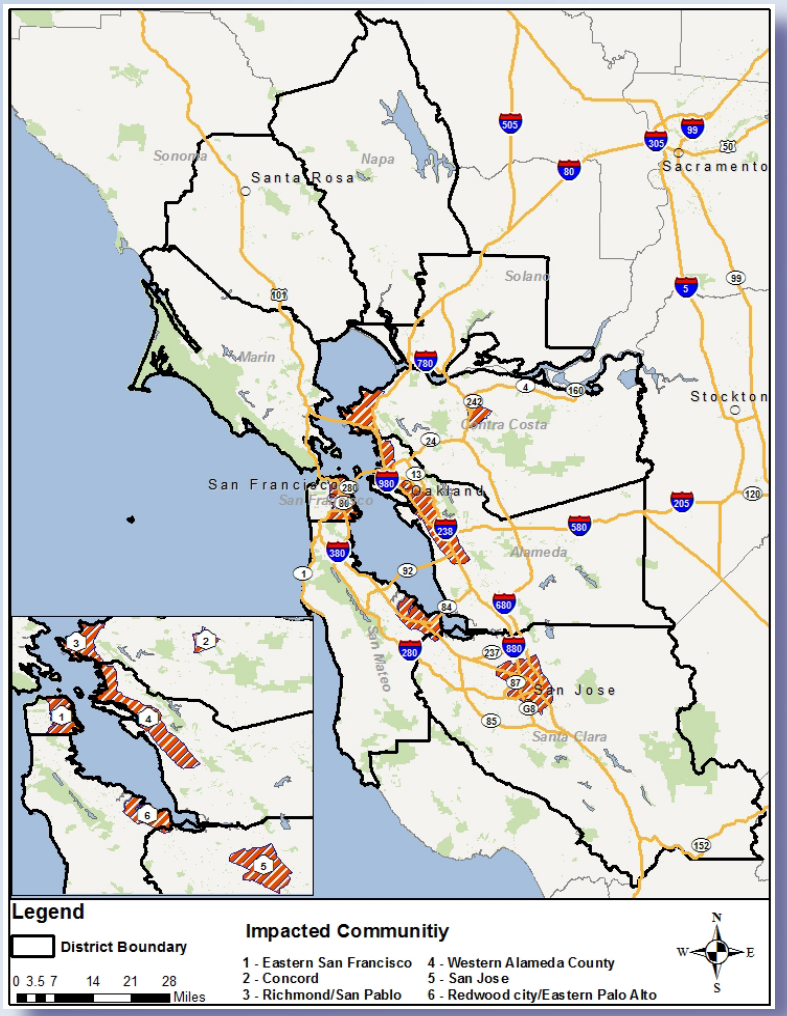
- Background
- Emissions Inventory Development
  - Data acquisition and processing
  - Composite emission factors development
  - Emission calculations
- Application: Dispersion Modeling
- Results and Conclusions
- Questions and Discussion

Background (1 of 2)

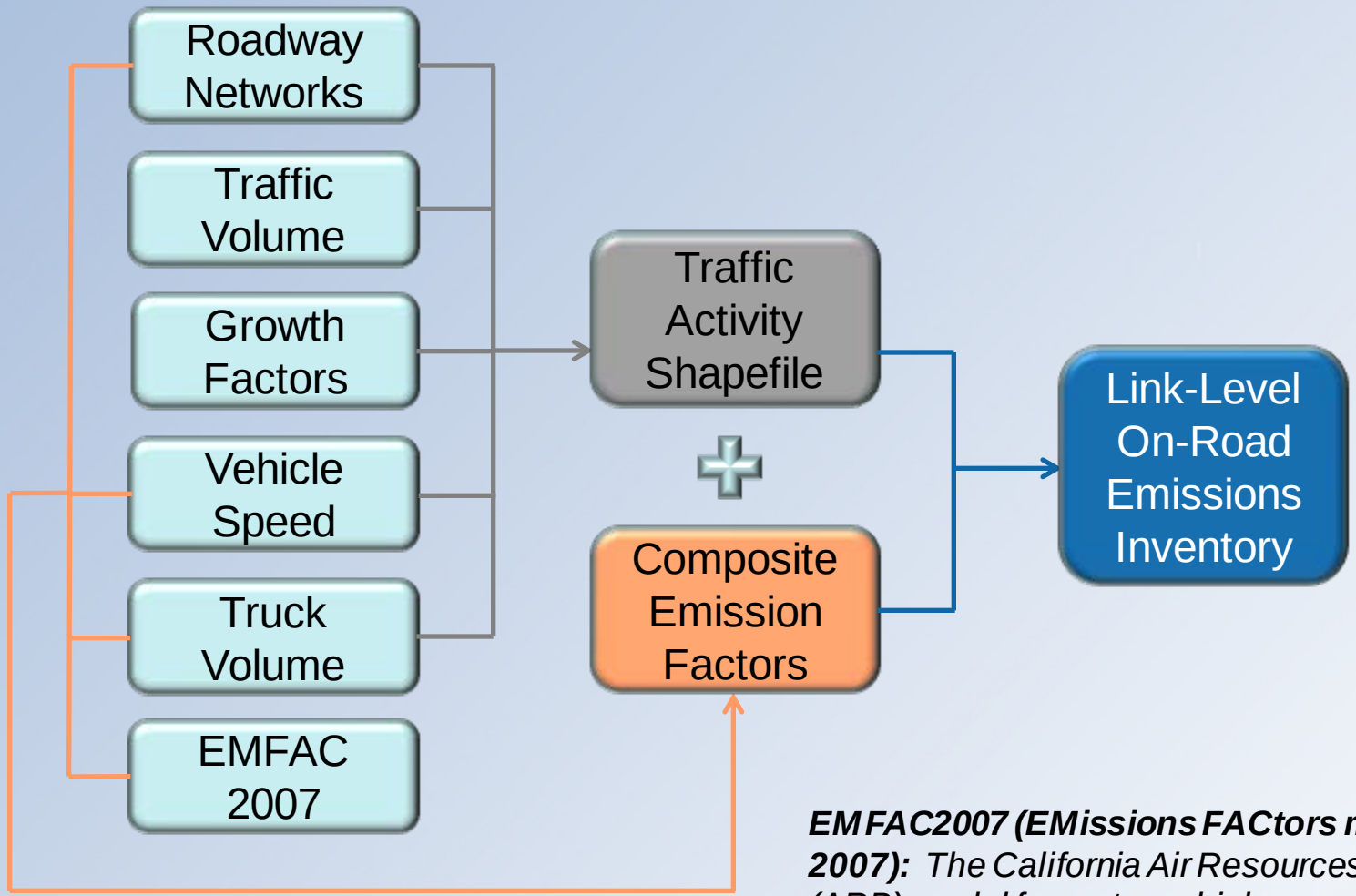
- The San Francisco Bay Area Air Quality Management District (the District) is developing guidance on preparing Community Risk Reduction Plans (CRRPs) for toxic air contaminants (TACs) and fine particulate matter ($PM_{2.5}$)
- These plans will allow for a comprehensive, community-wide approach to reducing local air pollutant emissions and exposures

Background (2 of 2)

- The District worked with Sonoma Technology, Inc. (STI) to generate the detailed emissions inventories (EI) needed for CRRPs
- Fine-scale on-road mobile source emissions inventories
  - State highways and major arterials
  - 2012–2082
  - Six communities



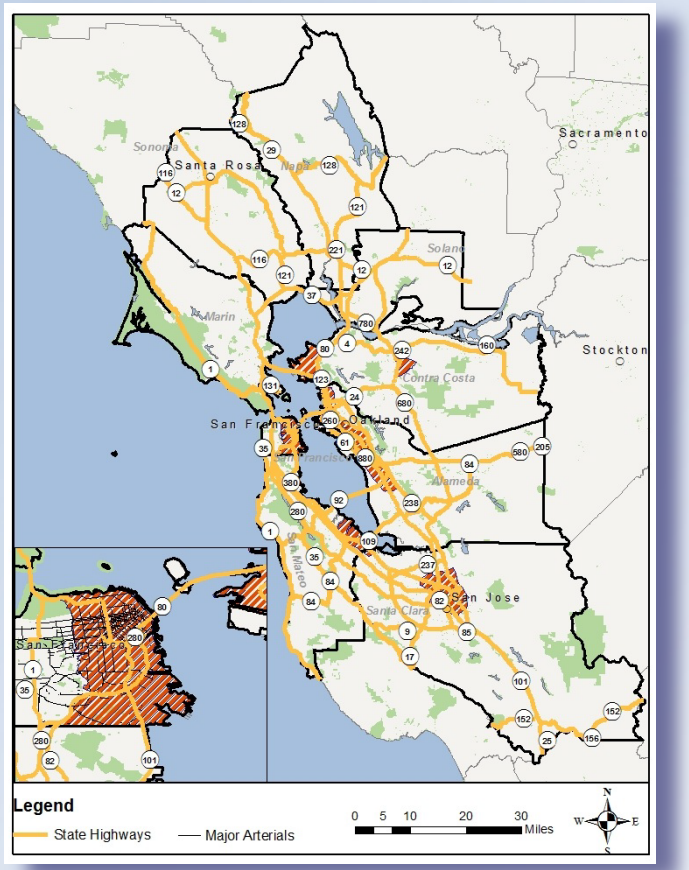
Emissions Inventory Development: Data Acquisition and Processing (1 of 4)



EMFAC2007 (EMissions FACtors model 2007): *The California Air Resources Board (ARB) model for motor vehicles*

Emissions Inventory Development: Data Acquisition and Processing (2 of 4)

- Road network
  - National Highway Planning Network (NHPN) shapefile
  - 2008 TIGER/Line shapefile
- Traffic volumes
  - 2009 annual average daily traffic (AADT) counts from Caltrans
  - Traffic count data from local agencies
  - BAYCAST-90 TDM and SF-CHAMP



TIGER: *The U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing database*
Caltrans: *California Department of Transportation*
BAYCAST-90 TDM: *Travel Demand Models for the San Francisco Bay Area*
SF-CHAMP: *San Francisco Chained Activity Modeling Process*

Emissions Inventory Development: Data Acquisition and Processing (3 of 4)

- Vehicle speed
  - BAYCAST-90 TDM and SF-CHAMP

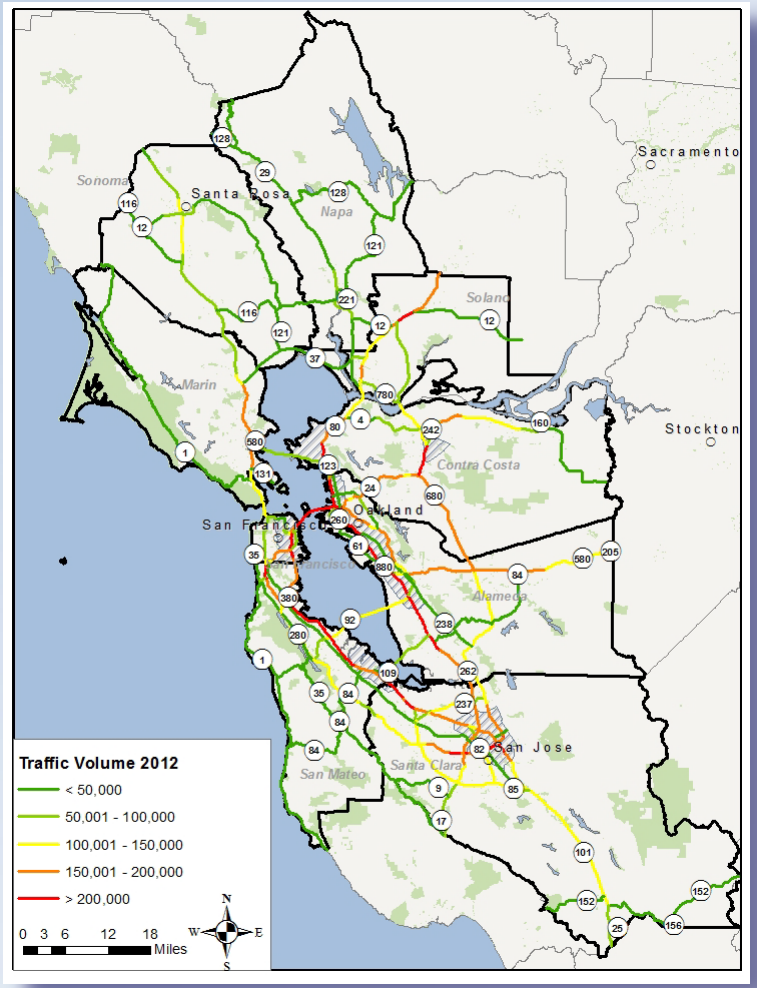
Period #	BAYCAST-90		SF-CHAMP	
	Abbreviation	Description	Abbreviation	Description
1	6MOR	Early Morning (0000-0600)	EA	Early Morning (0300-0600)
2	4AMPK	AM Peak (0600-1000)	AM	AM Peak (0600-0900)
3	5MID	Midday (1000-1500)	MD	Midday (0900-1530)
4	4PMPK	PM Peak (1500-1900)	PM	PM Peak (1530-1830)
5	5EVE	Evening (1900-2400)	EV	Late (1830-0300)

- Truck volume
  - Caltrans' 2009 truck AADT, local truck counts
  - BAYCAST-90 TDM and SF-CHAMP
  - Motor Vehicle Stock Travel and Fuel Forecast (MVSTAFF) report
  - Truck restrictions

Emissions Inventory Development: Data Acquisition and Processing (4 of 4)

- Adjustment factors
  - County specific
  - Vehicle miles traveled (VMT) data from ARB's EMFAC2007 model (2000–2012)

- Geospatial processing
  - Traffic activity was associated with road links in roadway networks
  - Road name, start/end nodes, and geographic proximity



Emissions Inventory Development: Composite Emission Factors Development (1 of 5)

- Adopt methodology similar to Caltrans' CT-EMFAC model
- Based on ARB's EMFAC2007 model

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Title     , SF_EF_2012-2040
Version   , Emfac2007 V2.3 Nov 1 2006
Run Date  , 2011/03/28 09,40,13
Scen Year, 2012 -- All model years in the range 1968 to 2012 selected
Season    , Annual
Area      , San Francisco
*******************************************************************************
Year,,2012,, -- Model Years,,1968, to ,2012, Inclusive --,,,Annual
     Emfac2007 Emission Factors, V2.3 Nov 1 2006

County Average,,,,,  San Francisco,,,,,,County Average

,,,,Table 1,  Running Exhaust Emissions (grams/mile; grams/idle-hour)

Pollutant Name, Total Organic Gases,,,,Temperature, 60F,,Relative Humidity, 66%

Speed,LDA,LDA,LDA,LDA,LDT1,LDT1,LDT1,LDT1,LDT2,LDT2,LDT2,LDT2,MDV,MDV,MDV,MDV,LHD1,LHD1,LHD1,LHD1,LHD2,LHD2,LHD2,LHD2,MHD,MHD,MHD,MHD,HHD,HHD,HHD,HHD,O
 MPH,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,D

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    5,  20.248,   0.272,   0.484,   0.331,  20.391,   0.371,   0.271,   0.454,  19.912,   0.357,   0.277,   0.386,  26.015,   0.520,   0.244,   0.556,
   10,  14.422,   0.181,   0.380,   0.223,  14.524,   0.251,   0.213,   0.310,  14.183,   0.239,   0.217,   0.259,  18.529,   0.346,   0.192,   0.372,
   15,  10.750,   0.127,   0.305,   0.158,  10.826,   0.178,   0.171,   0.223,  10.572,   0.168,   0.174,   0.183,  13.811,   0.242,   0.154,   0.262,
   20,   8.386,   0.093,   0.250,   0.118,   8.445,   0.133,   0.140,   0.168,   8.247,   0.124,   0.143,   0.136,  10.772,   0.178,   0.126,   0.194,
   25,   6.845,   0.072,   0.210,   0.092,   6.893,   0.104,   0.118,   0.132,   6.731,   0.096,   0.120,   0.106,   8.793,   0.138,   0.106,   0.151,
   30,   5.847,   0.059,   0.180,   0.076,   5.888,   0.085,   0.101,   0.109,   5.750,   0.078,   0.103,   0.086,   7.510,   0.112,   0.091,   0.123,
   35,   5.226,   0.050,   0.158,   0.065,   5.263,   0.073,   0.088,   0.095,   5.139,   0.067,   0.090,   0.074,   6.712,   0.095,   0.080,   0.105,
   40,   4.887,   0.045,   0.141,   0.059,   4.922,   0.065,   0.079,   0.086,   4.806,   0.059,   0.081,   0.067,   6.277,   0.085,   0.071,   0.094,
   45,   4.783,   0.042,   0.129,   0.056,   4.816,   0.061,   0.072,   0.081,   4.703,   0.056,   0.074,   0.063,   6.143,   0.080,   0.065,   0.089,
   50,   4.897,   0.041,   0.121,   0.056,   4.932,   0.060,   0.068,   0.080,   4.816,   0.055,   0.069,   0.062,   6.290,   0.078,   0.061,   0.088,
   55,   5.247,   0.043,   0.116,   0.058,   5.284,   0.062,   0.065,   0.083,   5.160,   0.056,   0.066,   0.064,   6.739,   0.081,   0.058,   0.091,
   60,   5.882,   0.046,   0.113,   0.064,   5.923,   0.066,   0.063,   0.091,   5.784,   0.061,   0.065,   0.069,   7.555,   0.088,   0.057,   0.099,
   65,   6.900,   0.053,   0.113,   0.073,   6.949,   0.075,   0.063,   0.104,   6.785,   0.069,   0.065,   0.079,   8.863,   0.100,   0.057,   0.113,
   70,   6.900,   0.053,   0.116,   0.073,   6.949,   0.075,   0.065,   0.104,   6.785,   0.069,   0.066,   0.079,   8.863,   0.100,   0.058,   0.113,
   75,   6.900,   0.053,   0.121,   0.073,   6.949,   0.075,   0.068,   0.104,   6.785,   0.069,   0.069,   0.079,   8.863,   0.100,   0.061,   0.113,


Pollutant Name, Carbon Monoxide,,,,Temperature, 60F,,Relative Humidity, 66%

Speed,LDA,LDA,LDA,LDA,LDT1,LDT1,LDT1,LDT1,LDT2,LDT2,LDT2,LDT2,MDV,MDV,MDV,MDV,LHD1,LHD1,LHD1,LHD1,LHD2,LHD2,LHD2,LHD2,MHD,MHD,MHD,MHD,HHD,HHD,HHD,HHD,O
 MPH,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,DSL,ALL,NCAT,CAT,D

    0,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,
    5, 168.637,   2.992,   2.827,   3.481, 168.669,   4.826,   2.315,   5.484, 165.775,   4.160,   2.336,   4.394, 279.973,   4.872,   2.242,   5.267,
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CT-EMFAC: Caltrans' California-specific version of EMFAC

Emissions Inventory Development: Composite Emission Factors Development (2 of 5)

Truck/non-truck classification

Vehicle Class ID	Vehicle Class	Abbr.	Truck Designation
1	Passenger Car	LDA	Non-truck
2	Light-Duty Trucks (0-3750 lb)	LDT1	
3	Light-Duty Trucks (3751-5750 lb)	LDT2	
4	Medium-Duty Trucks	MDV	
5	Light-Heavy-Duty Trucks (8501-10,000 lb)	LHDT1	Truck
6	Light-Heavy-Duty Trucks (10,000-14,000 lb)	LHDT2	
7	Medium-Heavy-Duty Trucks	MHDT	
8	Heavy-Heavy-Duty Trucks	HHDT	
9	Other Buses	OBUS	Non-truck
10	Urban Buses	UBUS	
11	Motorcycles	MCY	
12	School Buses	SBUS	
13	Motor Homes	MH	

Emissions Inventory Development: Composite Emission Factors Development (3 of 5)

- Truck only

$$EF_{Truck} = \sum_{vec=5}^{vec=8} EF_{vec} \times vmtTF_{vec}$$

$$vmtTF_{vec} = relativeVMT_{vec} / \sum_{vec=5}^{vec=8} relativeVMT_{vec}$$

where

EF_{Truck}	=	composite truck emission factor for the link average speed
EF_{vec}	=	emission factor by vehicle class
$vmtTF_{vec}$	=	vehicle class travel fraction relative to all trucks
$relativeVMT_{vec}$	=	vehicle class travel fraction relative to the whole fleet
vec	=	vehicle class ID, with trucks defined as classes 5-8

- Non-truck: same method

Emissions Inventory Development: Composite Emission Factors Development (4 of 5)

- Diesel truck emission factors

$$EF_{DSLTruck} = \sum_{vec=5}^{vec=8} EF_{vec,DSL} \times vmtTF_{vec,DSL}$$

$$vmtTF_{vec,DSL} = relativeVMT_{vec,DSL} / \sum_{vec=5}^{vec=8} relativeVMT_{vec,DSL}$$

where

$EF_{DSLTruck}$	=	composite diesel truck emission factor for the link average speed
$EF_{vec,DSL}$	=	emission factor by diesel vehicle class
$vmtTF_{vec,DSL}$	=	vehicle class travel fraction relative to all diesel trucks
$relativeVMT_{vec,DSL}$	=	vehicle class travel fraction relative to the whole fleet
vec	=	vehicle class ID, with trucks defined as the diesel-fueled portion of classes 5 to 8

- Diesel non-truck: same method

Emissions Inventory Development: Composite Emission Factors Development (5 of 5)

- All-vehicle emission factors

$$EF_{fleet} = EF_{Truck} \times TruckPect + EF_{NonTruck} \times NonTruckPect$$

where

EF_{fleet}	=	fleet-average composite emission factor for the link average speed
$TruckPect$	=	link-specific truck percentage
$NonTruckPect$	=	link-specific non-truck percentage
EF_{Truck}	=	composite truck emission factor for the link average speed
$EF_{NonTruck}$	=	composite non-truck emission factor for the link average speed

- Diesel vehicle only: same method

Emissions Inventory Development: Emission Calculations

$$Emis = EF_{fleet} \times VMT$$

$$TREmis = EF_{truck} \times VMT \times TruckPect$$

where

$Emis$	=	emissions in grams per day from all vehicles traveling on the road link
$TREmis$	=	emissions in grams per day from all trucks traveling on the road link
VMT	=	daily vehicle miles traveled on the road link, the product of traffic volume and length of the link

Diesel vehicles only: same method

Application: Dispersion Modeling

The fine-scale on-road mobile source emissions inventory was then used to model pollutant concentrations from vehicles:

- State highways
  - Rcaline (v0.95)
  - Meteorology
  - Keyhole Markup Language (KML) format
- Major arterials
  - AERMOD
  - Meteorology, dimension, and heights

Results and Conclusions (1 of 5)

Emissions inventory

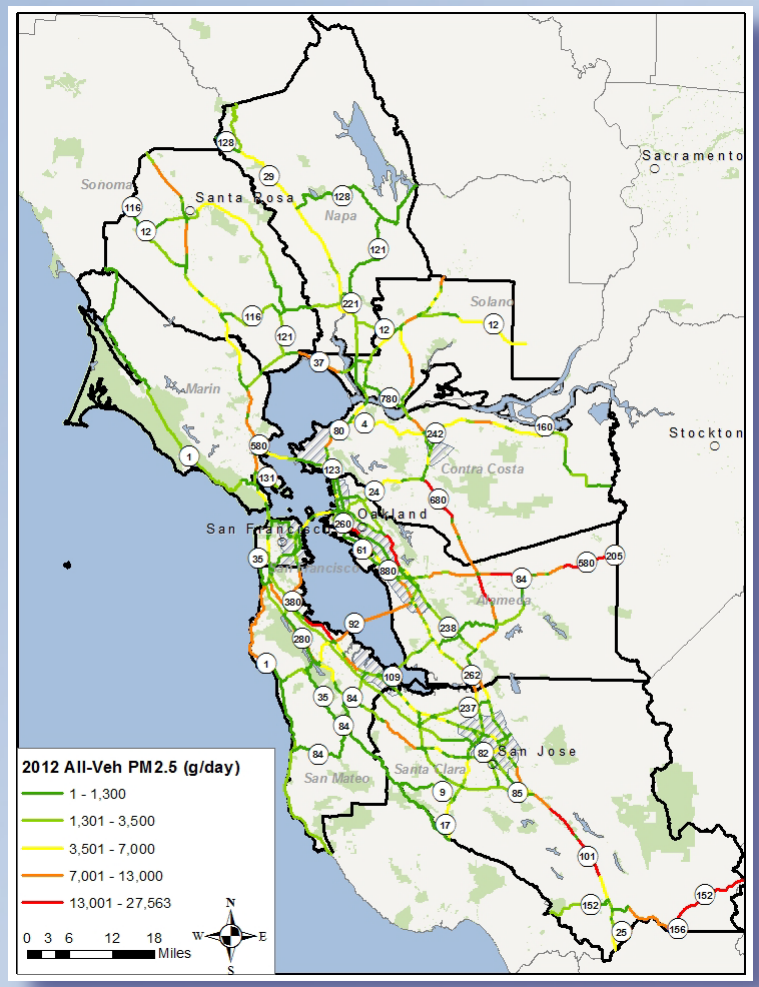
- Average day
- Link specific
- All-vehicle and truck-only
- 2012–2082
- Microsoft Access database
- Quality assurance: compared with ARB's statewide EI and UC Berkeley's fuel-based EI

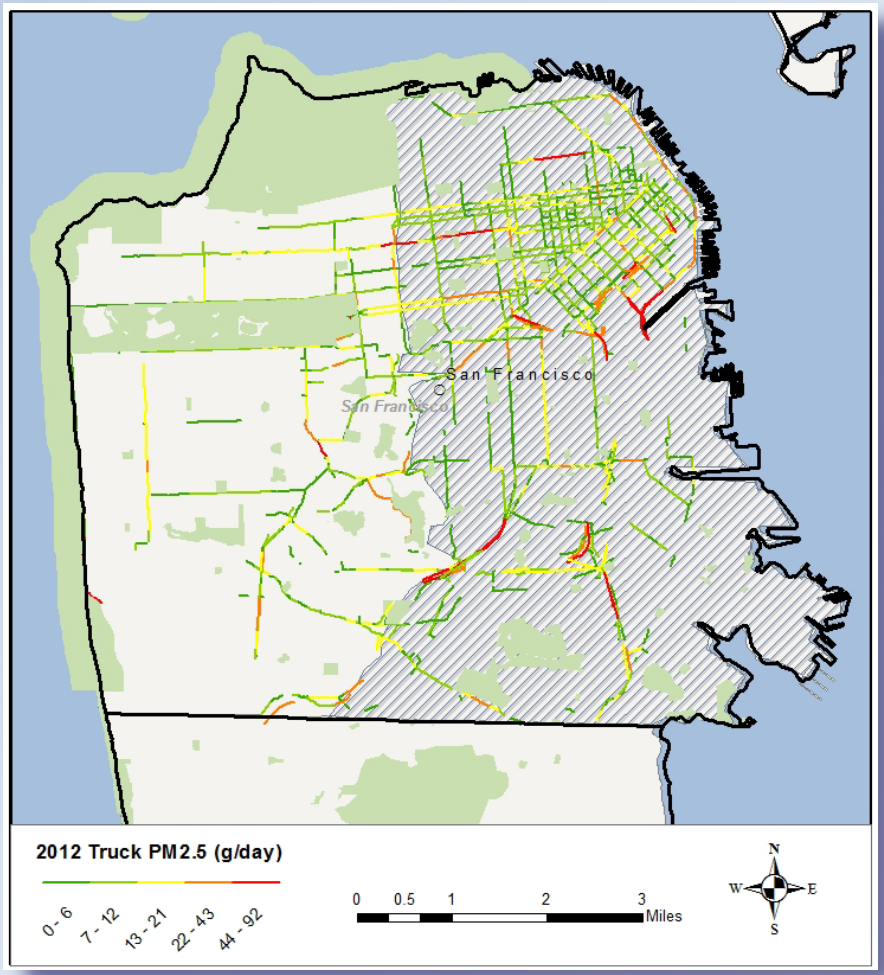
State Highways (Tons/day)

Pollutant	All Vehicles	Trucks	Truck Percentage
CO	252.52	13.30	5%
CO2	44,006	5,737	13%
DEOG	1.74	1.51	87%
DPM_{10}	1.13	1.01	89%
$DPM_{2.5}$	1.04	0.93	89%
NO_X	70.59	33.28	47%
PM_{10}	2.29	1.02	45%
$PM_{2.5}$	2.11	0.94	45%
SO_2	0.43	0.05	13%
TOG	19.15	1.94	10%

DEOG: *diesel organic gases*
DPM: *diesel particulate matter*

Results and Conclusions (2 of 5)

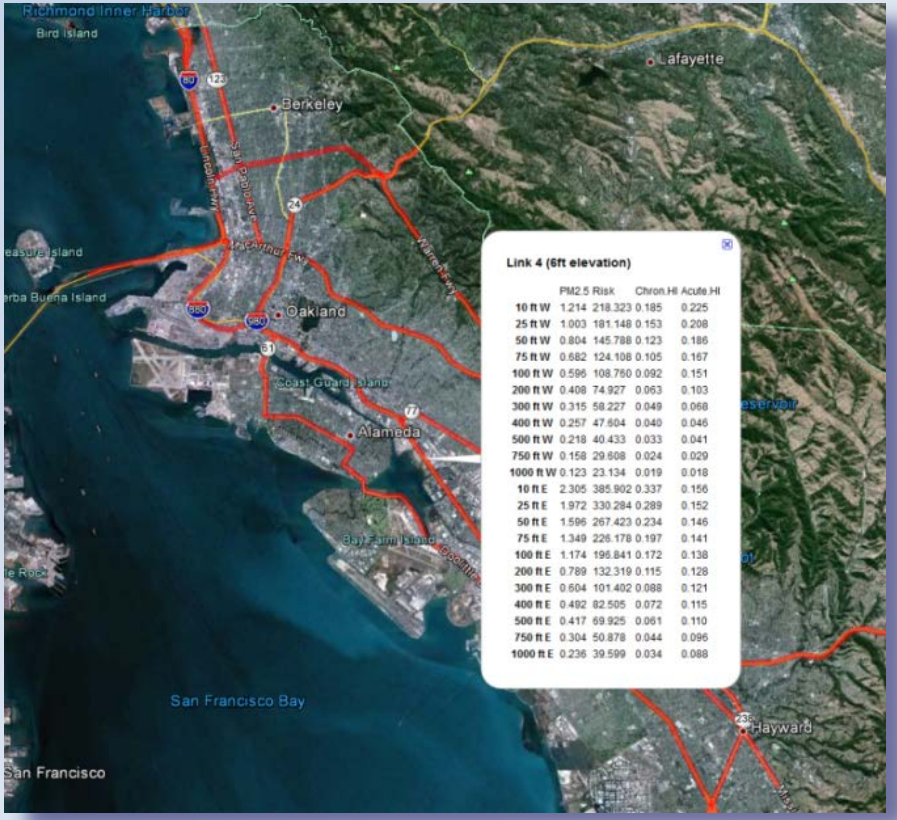




Results and Conclusions (3 of 5)

Dispersion modeling: Rcaline

- Near-road $PM_{2.5}$ concentrations, cancer risk, chronic/acute hazard index
- On both sides of each link at distances of 10, 25, 50, 75, 100, 200, 300, 400, 500, 750, and 1,000 ft.



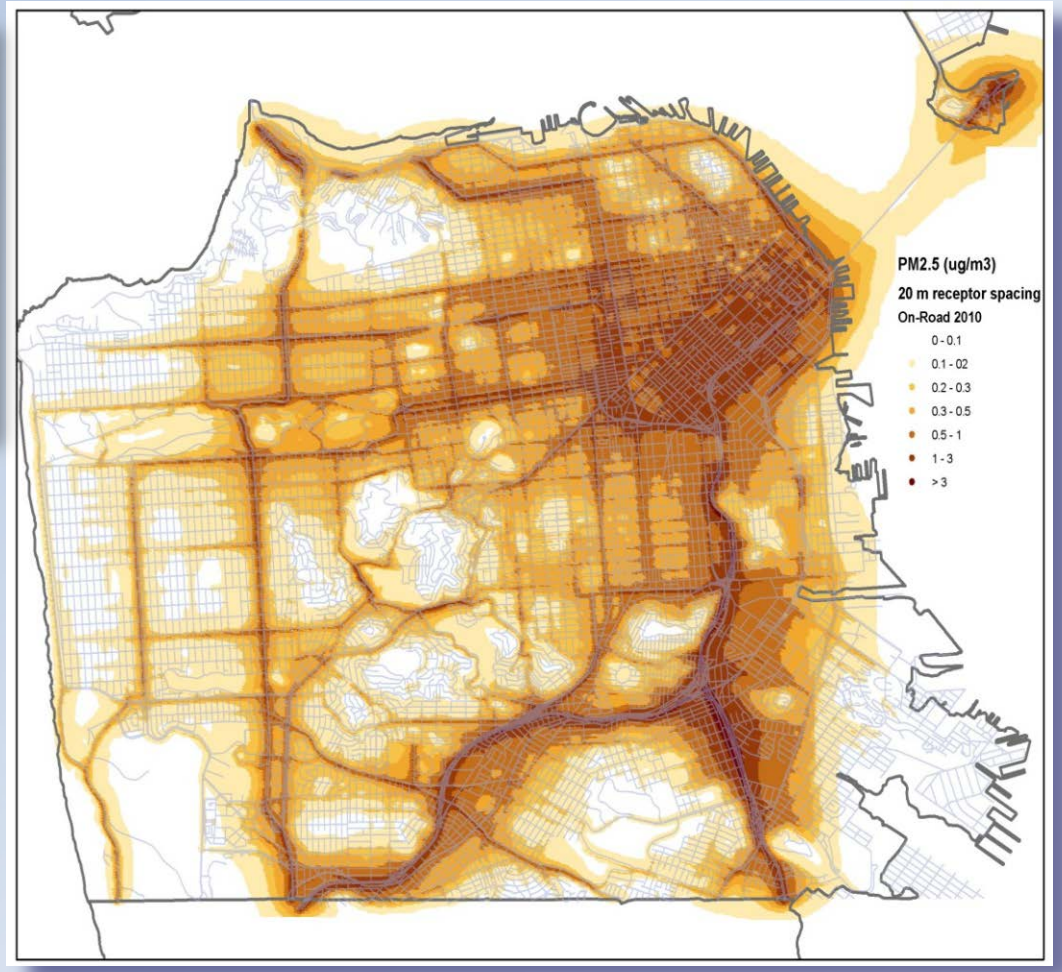
	PM2.5 Risk	Chron.HI	Acute.HI
10 ft W	1.214	218.323	0.185	0.225
25 ft W	1.003	181.148	0.153	0.208
50 ft W	0.804	145.788	0.123	0.186
75 ft W	0.682	124.108	0.105	0.167
100 ft W	0.596	108.760	0.092	0.151
200 ft W	0.408	74.927	0.063	0.103
300 ft W	0.315	58.227	0.049	0.068
400 ft W	0.257	47.604	0.040	0.046
500 ft W	0.218	40.433	0.033	0.041
750 ft W	0.158	29.608	0.024	0.029
1000 ft W	0.123	23.134	0.019	0.018
10 ft E	2.305	385.902	0.337	0.156
25 ft E	1.972	330.284	0.289	0.152
50 ft E	1.596	267.423	0.234	0.146
75 ft E	1.349	226.178	0.197	0.141
100 ft E	1.174	196.841	0.172	0.138
200 ft E	0.789	132.319	0.115	0.128
300 ft E	0.604	101.402	0.088	0.121
400 ft E	0.492	82.505	0.072	0.115
500 ft E	0.417	69.925	0.061	0.110
750 ft E	0.304	50.878	0.044	0.096
1000 ft E	0.236	39.599	0.034	0.088

Available at http://www.baaqmd.gov/Divisions/Planning-and-Research/CEQA-GUIDELINES/Tools-and-Methodology.aspx

Results and Conclusions (4 of 5)

Dispersion modeling: AERMOD

Direct contribution of on-road mobile $PM_{2.5}$ concentration and cancer risk on a dense network of receptor locations



Results and Conclusions (5 of 5)

Fine-scale emission inventories become increasingly important

- Input to city-level air pollution dispersion modeling
- Fine-scale spatial mapping, detailed activity data and composite emission factors, plus compilation into modern database structures accessible to automated programming tools are key to generating detailed maps of air quality risk at the city scale
- Detailed air pollution maps help health and planning agencies identify areas with high risk and the sources that contribute to them to protect public health from exposure to local air pollution sources

Questions and Discussion

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