Emissions Inventory and Chemical Transport Modeling

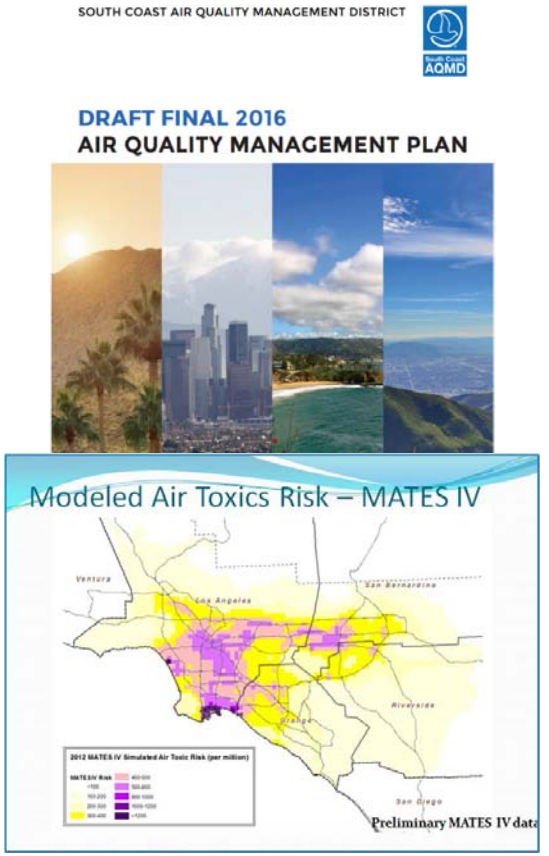
Assembly Bill (AB) 617
Community Air Initiatives

Technical Advisory Group Meeting

February 27, 2019

Overview

- Emissions and air quality modeling used to support the Air Quality Management Plan (AQMP) and the Multiple Air Toxics Exposure Study (MATES)
- Use of state-of-the-art modeling tools
- Use of modeling tools are peer reviewed in the scientific literature and during the Scientific, Technical & Modeling Peer Review (STMPR) Advisory Group meetings
- Modeling tools are in constant development and improvement



Why do we need these tools?

Based on ARB's Blueprint for Community Emissions Reduction Programs:

Need to identify air pollution challenges facing the community:

- Baseline emissions from which emission reductions can be measured (i.e., source attribution analysis)
- Sources contributing to cumulative exposure burden

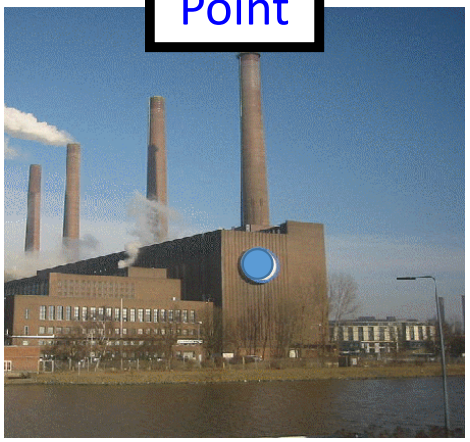
Develop strategies to reduce emissions and quantify results:

- Evaluate emission reductions from community strategies
- Quantify resulting reduction in exposure burden

Development of Emissions Inventory

Emission Source Categories

Point



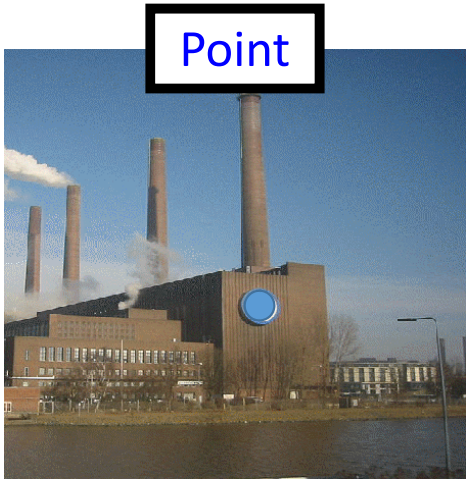
Area

On-road Mobile

Off-road Mobile

South Coast AQMD

Methodology for Point Source Emissions



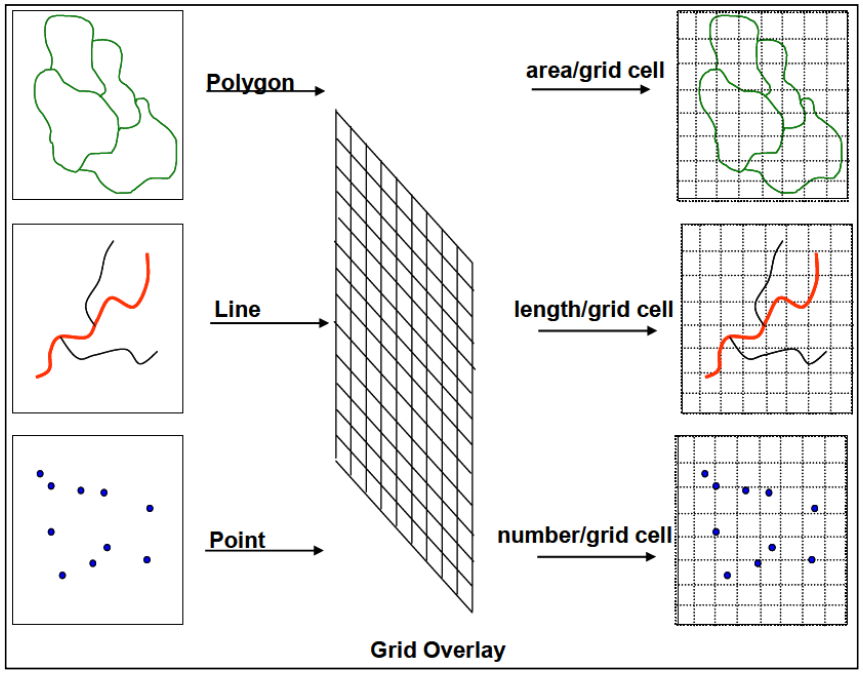
- Emissions from Annual Emissions Reporting (AER) Program
  - Approximately 2,000 facilities required to report
- Facilities that emit more than 4 tons/year of VOC, NOX, SOX or PM, or more than 100 tons/year of CO
  - Emissions categorized by USEPA's SCC
  - AER emissions combined with permit data
  - Business operation activity profile is recorded so annual emissions are distributed throughout day, week and year
- Toxic emissions calculated based on CARB speciation profiles for VOC and PM, based on SCC classification
- Consolidation of AB 2588 toxics emission inventory reporting requirements into the AER program (~ 177 toxics compounds)

Methodology for Area Source Emissions

- Emissions developed jointly by AQMD and CARB
  - CARB developed categories associated with consumer products, architectural coatings and degreasing (239 categories)
  - AQMD developed remaining 93 categories
  - Methodology for area sources is specific for each category
- Emissions spatially allocated to a 2km by 2km grid using spatial surrogates
  - Typical surrogates include: population, VMT, total employment, industrial and retail employment, housing, land cover types
- Toxic emissions calculated based on CARB speciation profiles for VOC and PM

Methodology for Area Source Emissions (Cont.)

- Distributed by a surrogate that best represents location of emissions

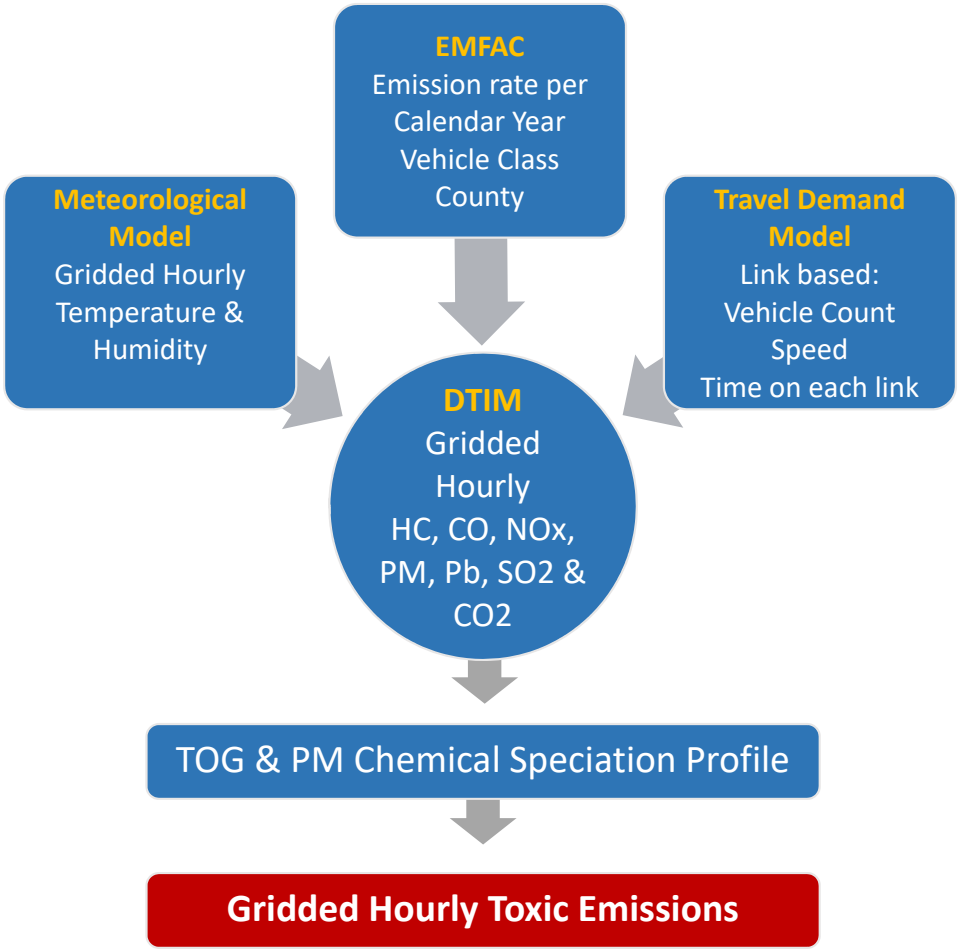


Common Surrogates
Population
VMT
Length of rail per grid cell
Locations of unpaved rural roads
Total housing
Agricultural land cover
National forest > 5000 ft
Total employment
Industrial employment
Retail employment
Single dwelling units
Rural land cover – forest
Rural land cover – range land

Methodology for On-road Source Emissions

- On-road emissions are calculated by combining vehicle emission factors and vehicular activity
- Emission factors are obtained from EMFAC
  - Emission factor for a given vehicle type depend on speed, temperature, relative humidity
- Link-based vehicular activity is obtained from SCAG
  - Volumes and speeds for LD, MD and HD are available at the transportation link level for 5 discrete periods of time (morning, midday, afternoon, evening, night) which are then distributed to 24 hour profiles
  - Day-of-week profiles are used to generate distinct emissions for Mon, Wed-Thu, Fri, Sat and Sun
- Direct Travel Impact Model (DTIM) is used to link emission factors and vehicle activity
  - DTIM uses hourly gridded temperature and RH values to calculate hourly gridded emissions using SCAG's data
- Toxic emissions calculated based on CARB speciation profiles for VOC and PM

Methodology for On-road Source Emissions (Cont.)



Methodology for Off-road Source Emissions

- CARB's OFF-ROAD model used for off-road categories
  - Except commercial ships, aircraft, locomotive and recreational vehicles
- OFF-ROAD includes:
  - population, activity, horsepower, load factors, and emission factors to yield the annual equipment emissions by county, air basin, or state
  - Spatial and temporal features are incorporated to estimate seasonal emissions
- Aircraft emissions developed by SCAQMD and allocated over the airports
- Ship emissions developed by CARB
- All emissions are allocated on the 2km by 2km grid, using spatial surrogates
- Toxic emissions calculated based on CARB speciation profiles for VOC and PM, based on SCC classification
- 2012 emissions are projections from 2008

Data Availability

- Emissions data readily available from MATESIV and 2016 AQMP for the year 2012 and future projections
- Additional resources include annual emissions reporting system data
- MATES V is underway, will provide data for future refinements of inventory and exposure analysis

South Coast AQMD

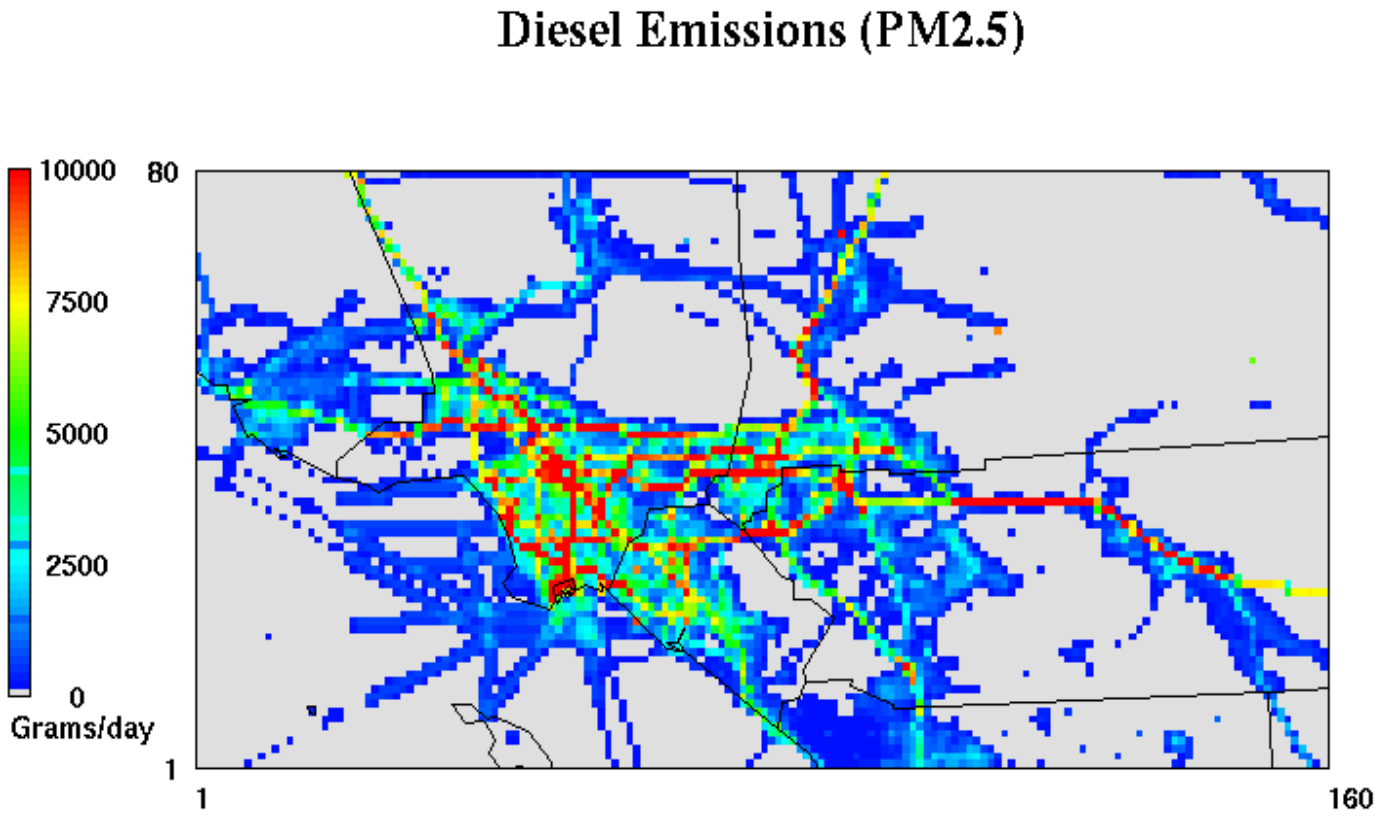
Air Toxics

- selected compounds apportioned by the on-road, off-road, point, and area source categories are listed below

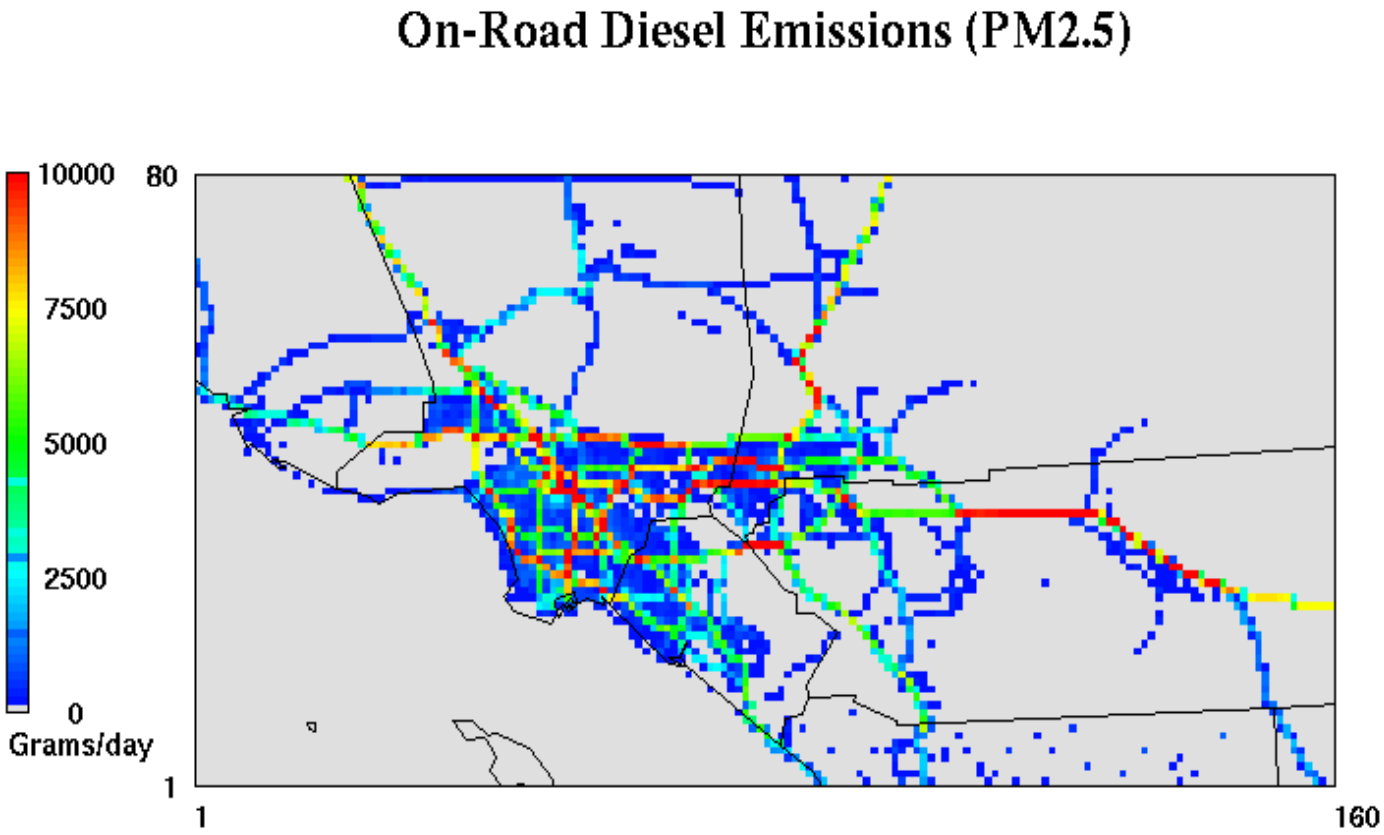
Table 3-4. 2012 Annual Average Day Toxic Emissions for the South Coast Air Basin.

	Pollutant	Emissions (lbs/day)				
		On-road	Off-road	Point	Area	Total
√	Acetaldehyde*	2066.9	3083.1	108.1	1378.7	6636.9
	Acetone**	1796.1	2342.3	379.8	20569.3	25087.4
√	Benzene	5336.3	4477.1	711.8	1506.5	12031.7
√	1,3-Butadiene	1002.5	1028.7	435.2	107.2	2573.6
√	Carbon tetrachloride	0.0	0.0	6.6	0.1	6.7
√	Chloroform	0.0	0.0	12.7	0.8	13.5
√	1,1 Dichloroethane	0.0	0.0	0.3	65.3	65.5
√	1,4 Dioxane	0.0	0.0	0.1	0.0	0.1
√	Ethylene dibromide	0.0	0.0	0.1	0.0	0.1
√	Ethylene dichloride	0.0	0.0	53.8	11.4	65.2
√	Ethylene oxide	0.0	0.0	4.9	0.0	4.9
√	Formaldehyde*	5159.8	7530.0	1678.2	4517.8	18885.8
	Methyl ethyl ketone*	335.1	423.2	870.8	5425.6	7054.7
√	Methylene chloride	0.0	0.0	26.2	9874.3	9900.5
√	MTBE	0.0	1.1	0.1	0.0	1.2
√	Naphthalene	264.0	194.8	16.7	220.4	695.9
√	p-Dichlorobenzene	0.0	0.0	70.3	2945.1	3015.5
√	Perchloroethylene	0.0	0.0	805.0	5865.4	6670.4

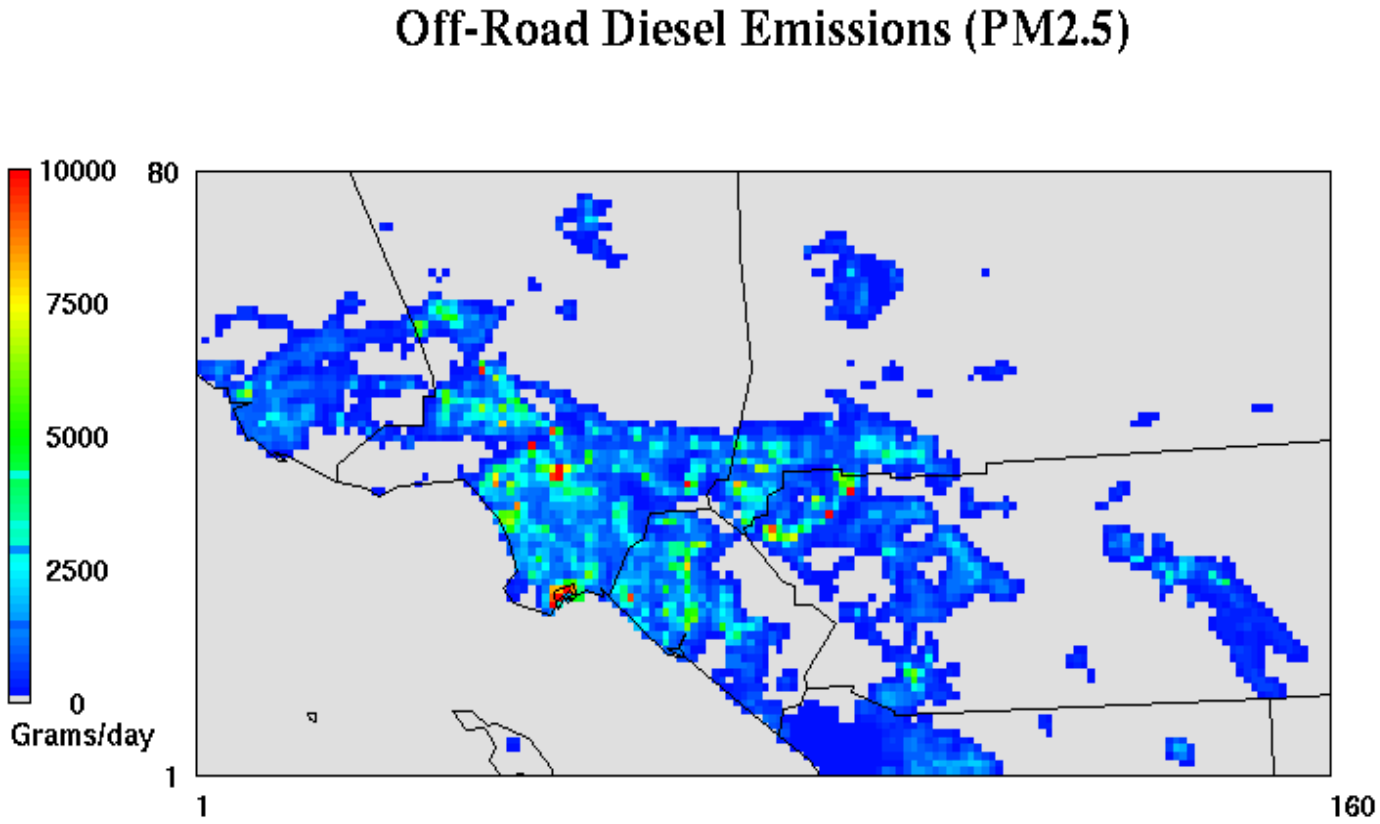
Total Diesel PM Emissions



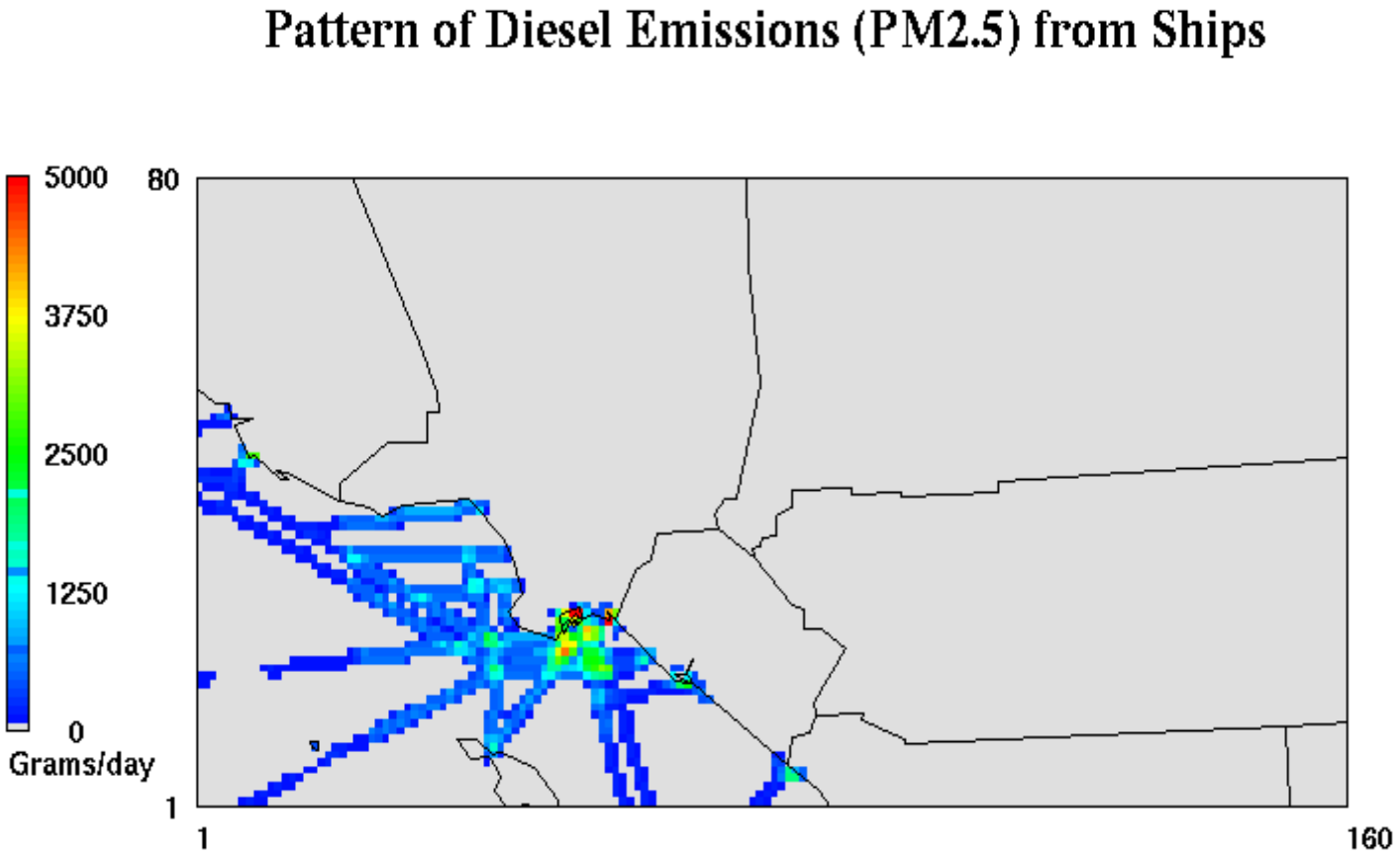
Diesel PM emissions from On-Road



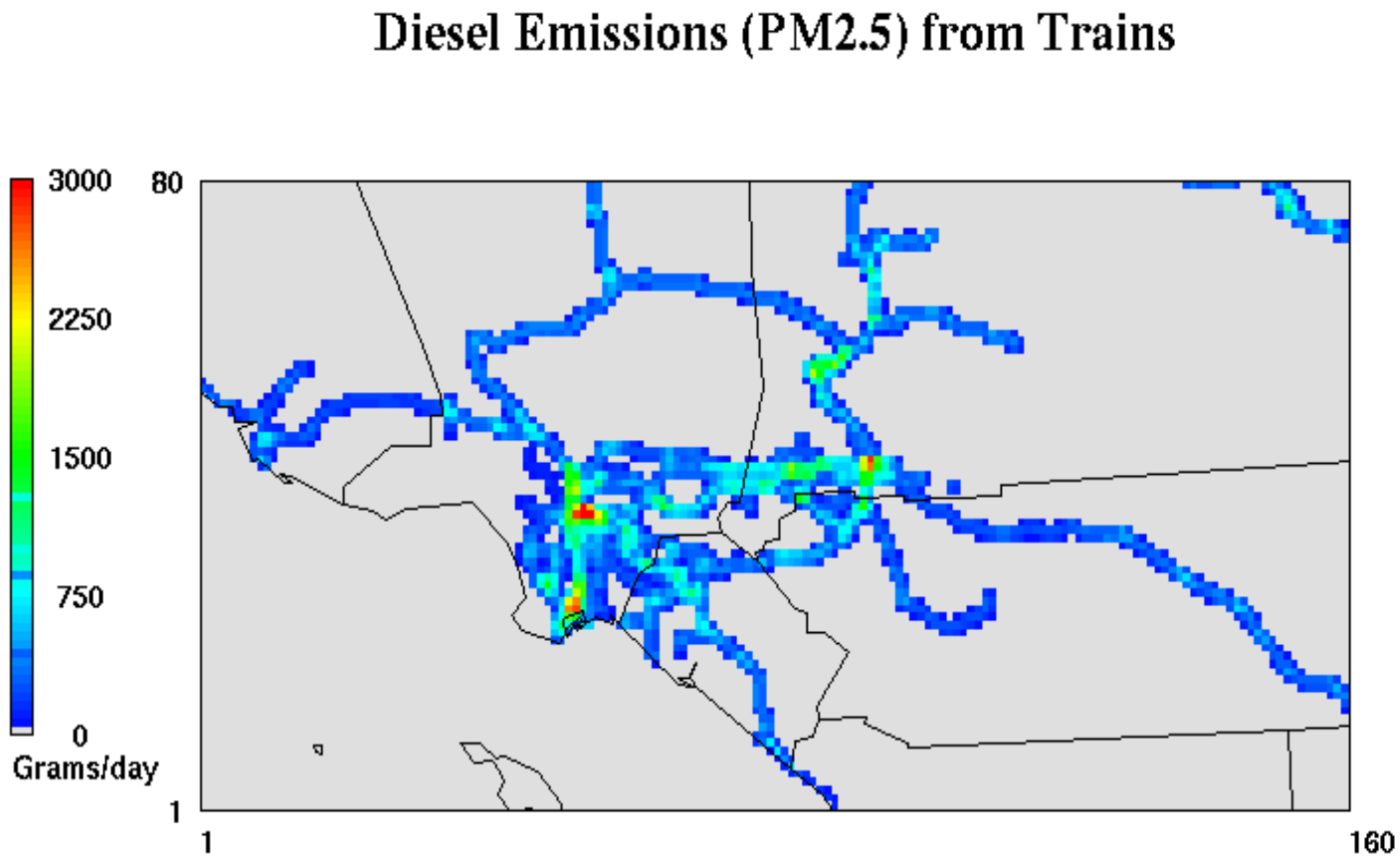
Diesel PM emissions from Off-Road



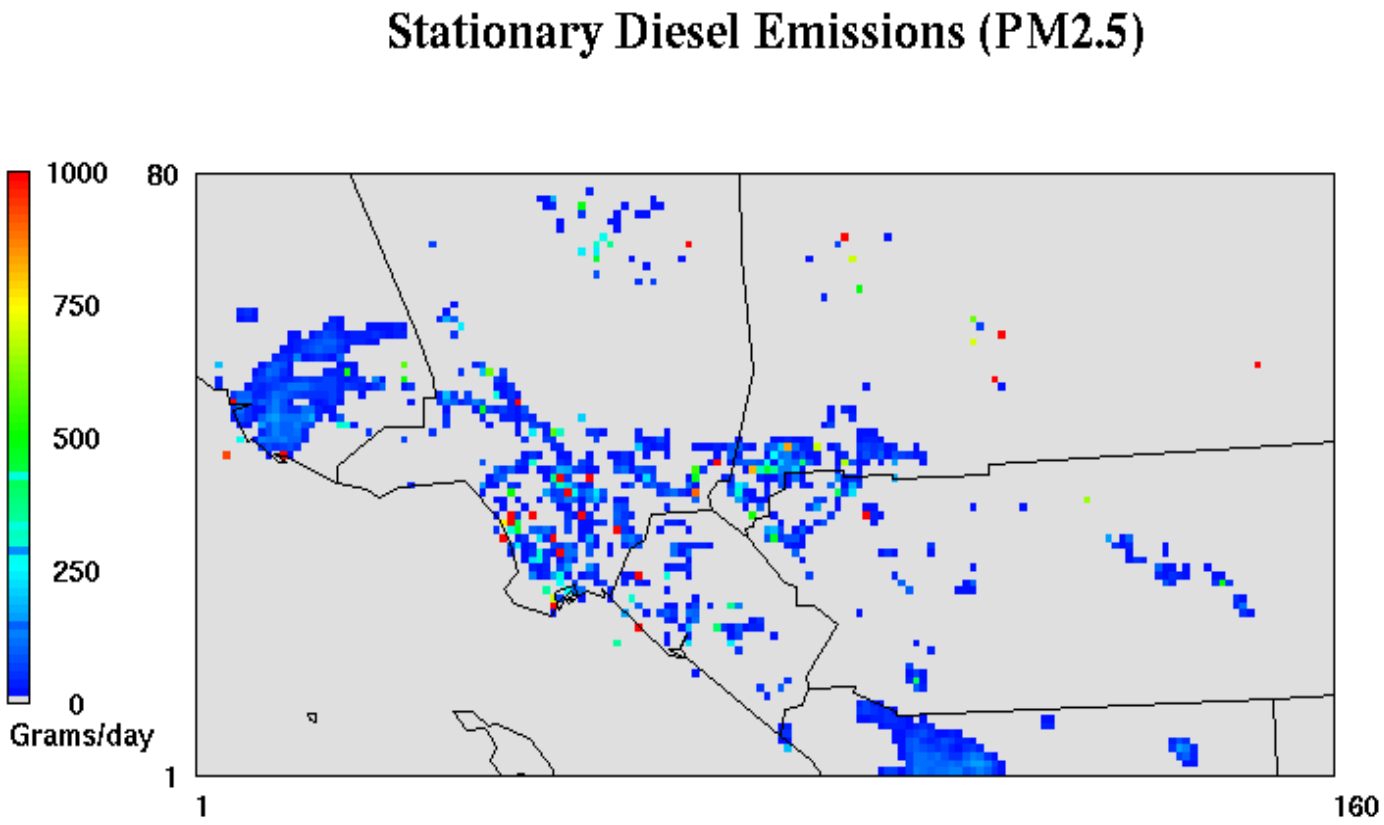
Diesel PM emissions from Ships



Diesel PM emissions from Trains



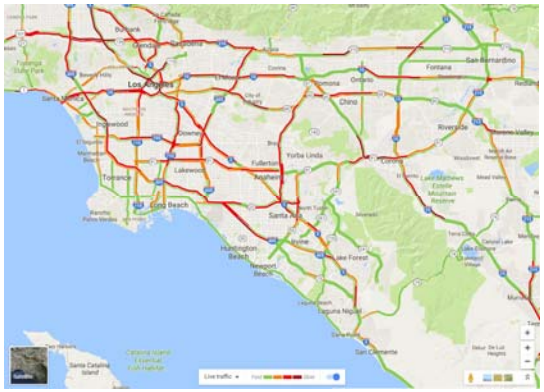
Diesel PM emissions from Stationary



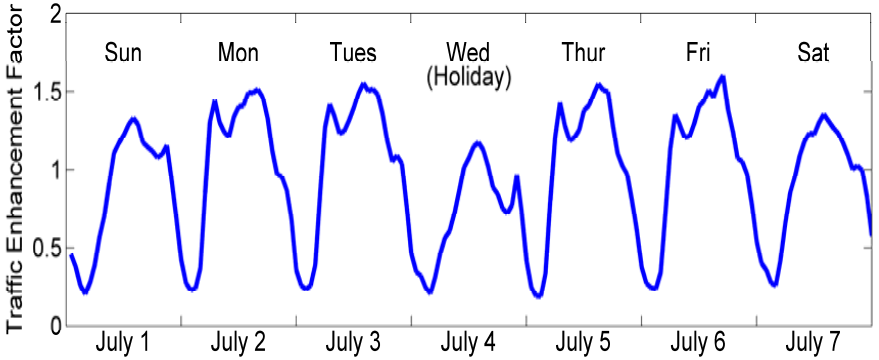
Employing State-of-Art Real-time Measurements and Methodologies to Improve Emissions Inventory

Improvements: On-Road Emissions Inventory

- The 2016 AQMP inventory was developed based on traffic sensor measurements data



Light & Medium Duty Traffic Volume near Los Angeles downtown in 2012

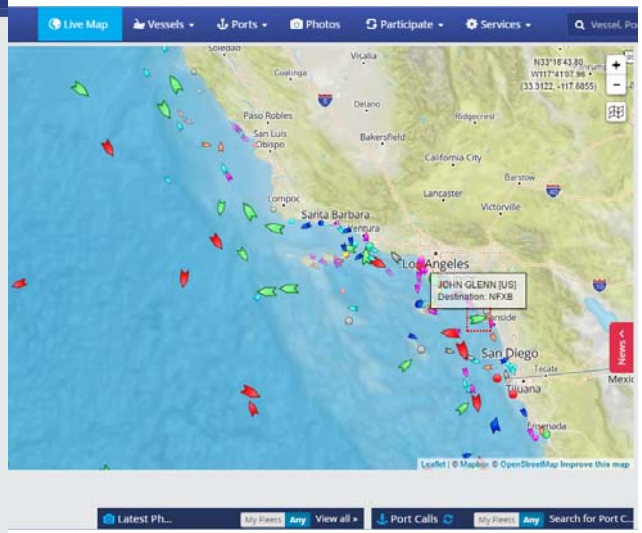


- Further improvement specifically in heavy-duty vehicle category are under development.

Improvement in Ocean Going Vessels: Example of ship data near Port of LA

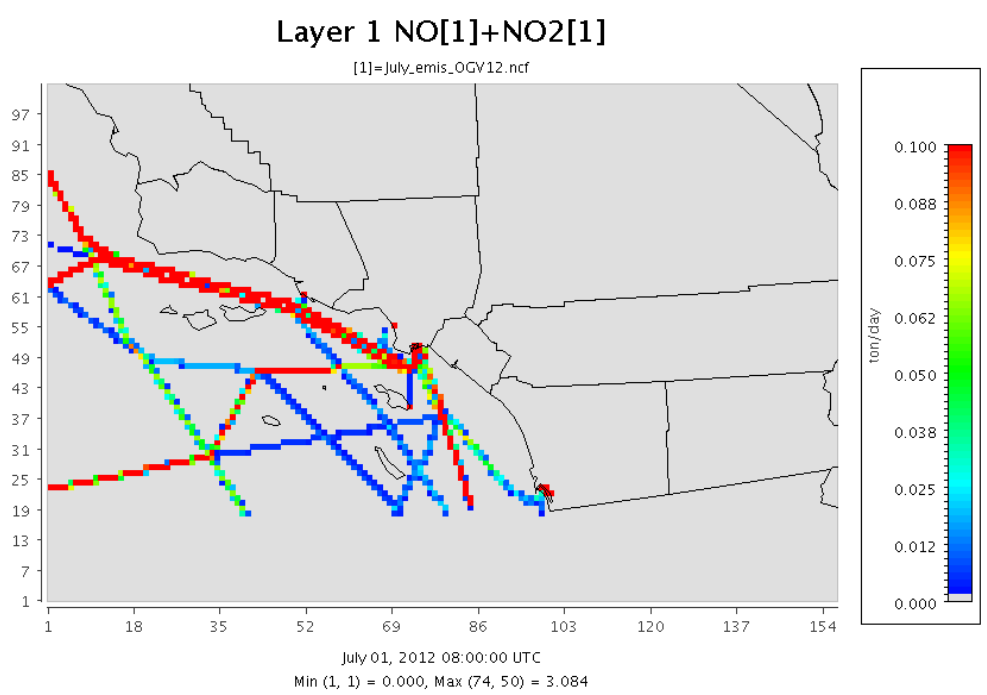
MarineTraffic | Live Map | Vessels | Ports | Photos | Participate | Services | Vessel

Flag	Vessel Name	Photo	Type	Ship Type	Length × Breadth (m)	Deadweight	Area	Received	Destination / Reported ETA	My Fleet
	MANDO	Photos: 20		Container Ship	153x25	17250	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	TRIESTE 2017-07-02 08:00 LT (UTC +2)	Add to Fleet
	ULUSOY-14	Photos: 28		Ro-Ro/Vehicles Carrier	208x26	15000	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	ITTRS-TRCES 2017-06-30 08:30 LT (UTC +3)	Add to Fleet
	TALOS	Photos: 190		Ro-Ro/Vehicles Carrier	124x19	2838	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	PEIRAIAS 2017-06-30 13:30 LT (UTC +3)	Add to Fleet
	AS FLORIANA	Photos: 76		Container Ship	166x25	18445	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	FOR ORDER 2017-06-04 22:00 (UTC)	Add to Fleet
	LUCKY JOY	Photos: 53		General Cargo	109x17	7158	East Mediterranean	2017-06-30 00:14 LT (UTC +2)	CASTELLON 2017-07-05 15:00 LT (UTC +2)	Add to Fleet
	ALLEGRA	Photos: 49		Bulk Carrier	180x30	34146	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	DERINCE 2017-07-01 12:00 LT (UTC +3)	Add to Fleet
	NEW GEMINI	Photos: 20		General Cargo	96x15	5269	Aegean Sea	2017-06-30 00:14 LT (UTC +2)	MARGHERA 2017-07-03 14:00 LT (UTC +2)	Add to Fleet

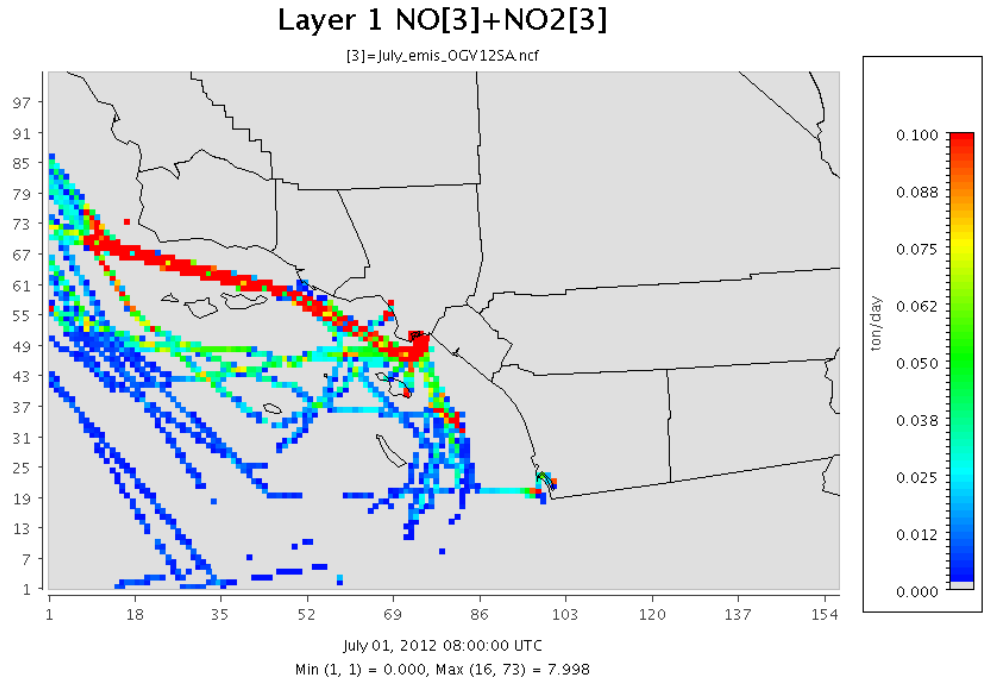


NOx Emissions from Ocean Going Vessels

Default Distribution



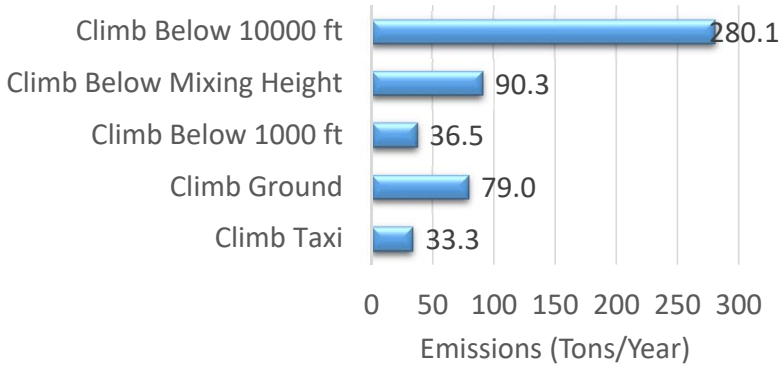
Updated Distribution



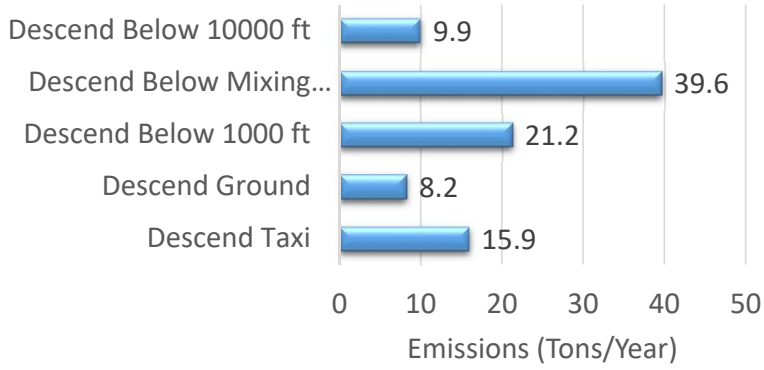
Altitude Resolving Aircraft Emissions

- Currently aircraft emissions are treated as ground level release

NOx Emissions During Ascending (John Wayne Airport)



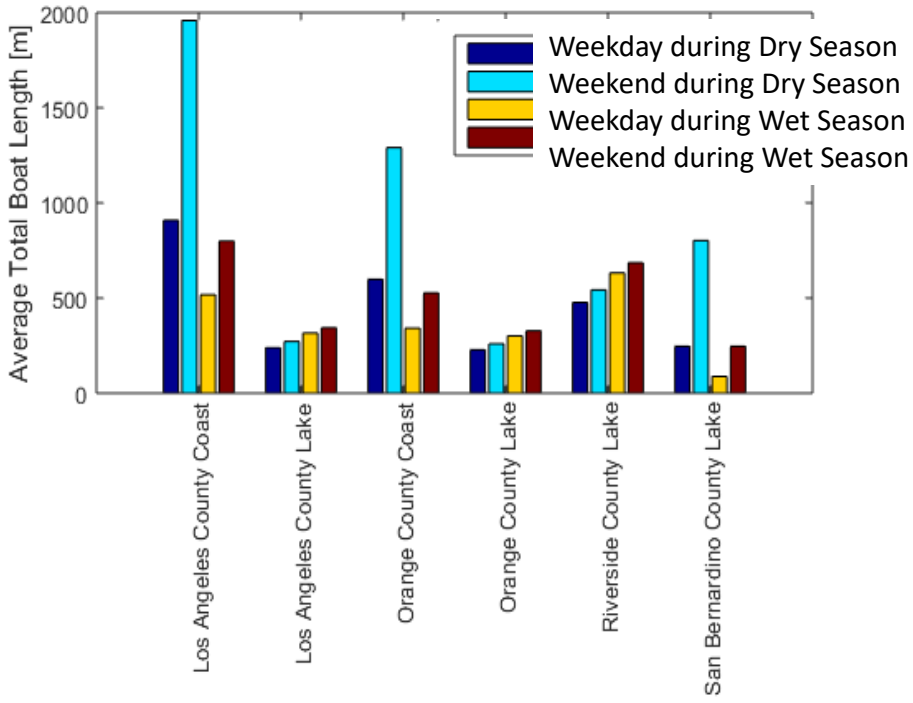
NOx Emissions During Descending (John Wayne Airport)



Temporal Allocation of Recreational Boats

- This category accounts for 10% of the total VOC emissions
- High implication in simulating Weekdays vs. Weekends.
- Manually identify type and measure boats throughout SoCAB *(only boats in motion were included)*
- From high resolution aerial photos on Google Earth since 2002 (~6 per site)

vs



Improvement in Urban Biogenic Emissions

- Working on using high-resolution (10m) Sentinel Satellite data to obtain Leaf Area Index and vegetation cover to provide inputs for urban canopy emissions
  - There is no information on urban vegetation from standard resolution satellite product, so emissions from urban canopy are underestimated
  - Need to improve our understanding of vegetation species used in urban environments, and their specific emission factors

High-Resolution Sentinel Satellite Image Processing

Vuolo et al, 2016, Remote Sens. 2016, 8, 938; doi:10.3390/rs8110938

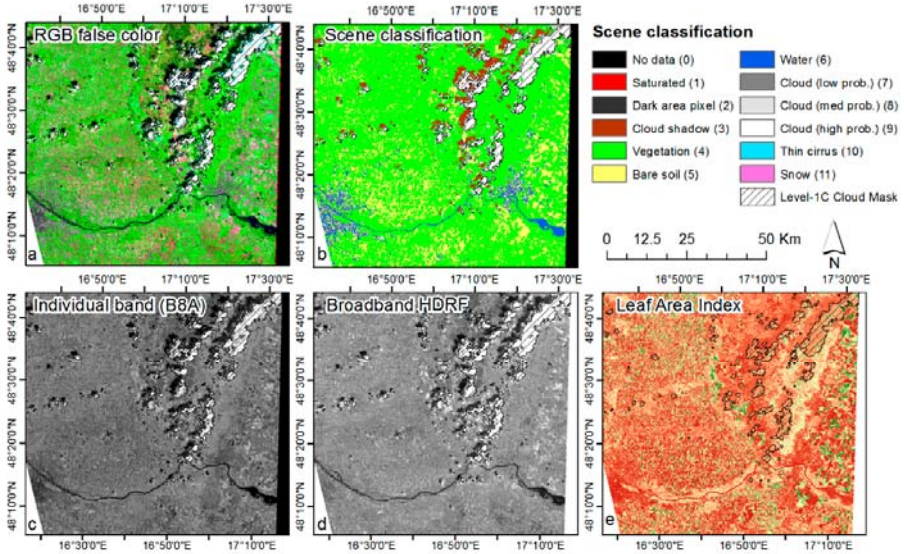
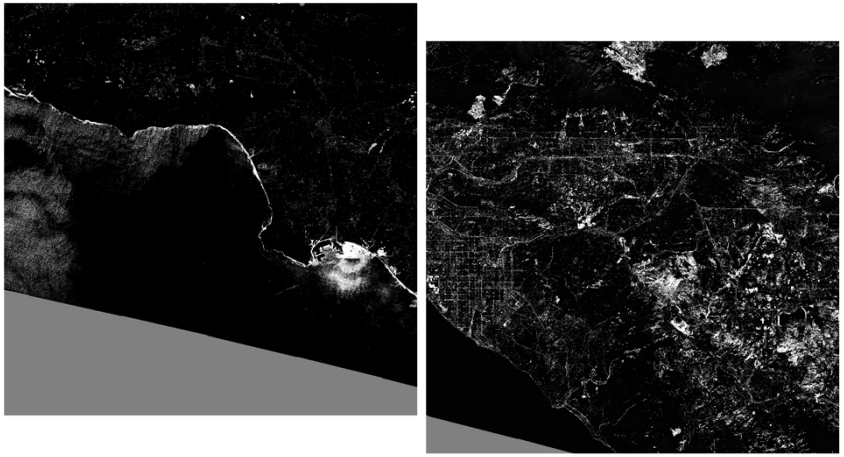


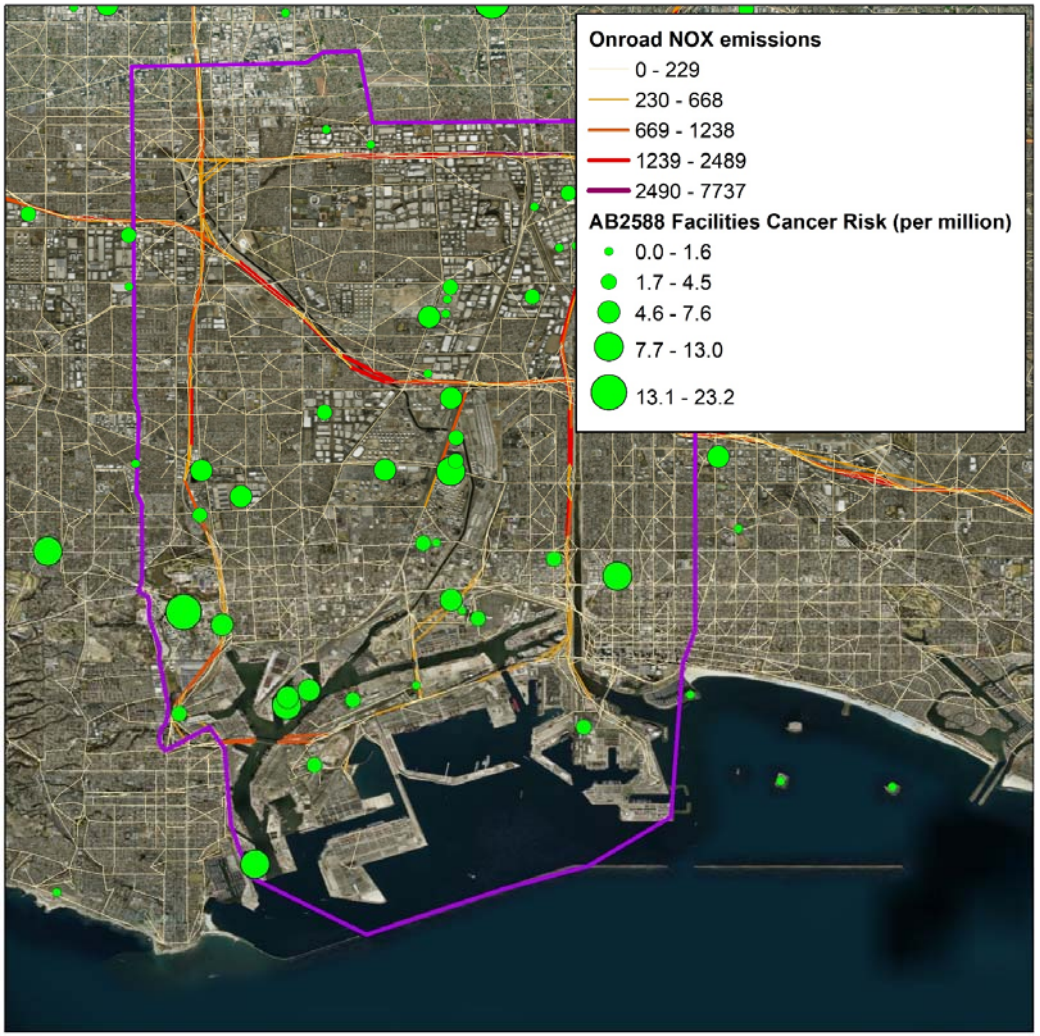
Figure 1. Examples of a Sentinel-2 100 × 100 km^2 images (tile 33UXP, covering the region between Vienna and Bratislava, acquired on 6 May 2016) and value-added products available at the data service platform. Note that clouds extracted from the Level-1C cloud mask are displayed (as hashed symbol) in all other products. (**a**) RGB false color composite; (**b**) Scene classification; (**c**) Individual band; (**d**) Broadband hemispherical-directional reflectance factor (HDRF); (**e**) Leaf Area Index.

10m Resolution Sentinel Images for South Coast Air Basin



Future Improvements

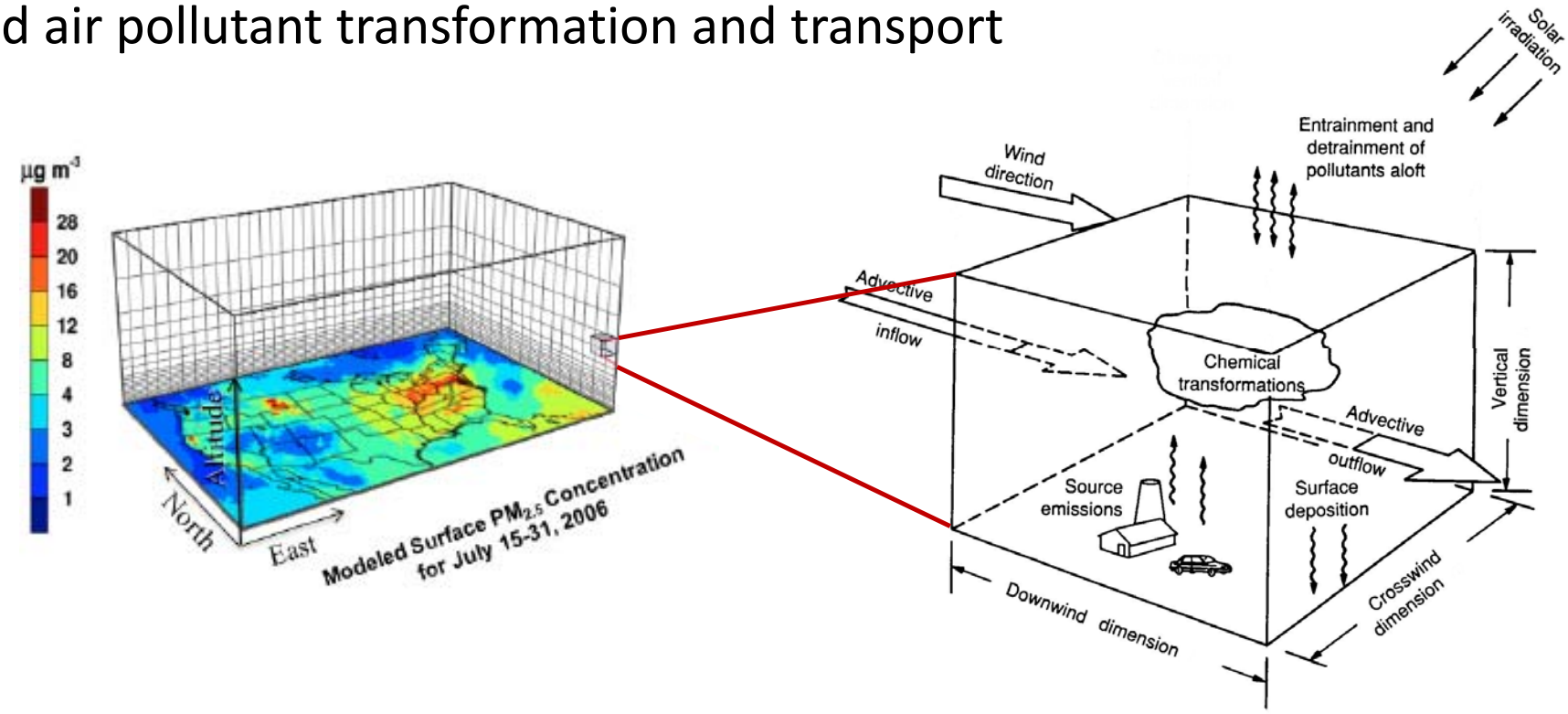
- Increase emissions resolution from 2 km by 2 km grid to finer scale:
  - Spatial distribution of on-road sources at the transportation link level
  - Point source information from major polluters
  - Fuel stations specific information
  - Specific heavy-duty truck stops locations



Chemical Transport Modeling Platform

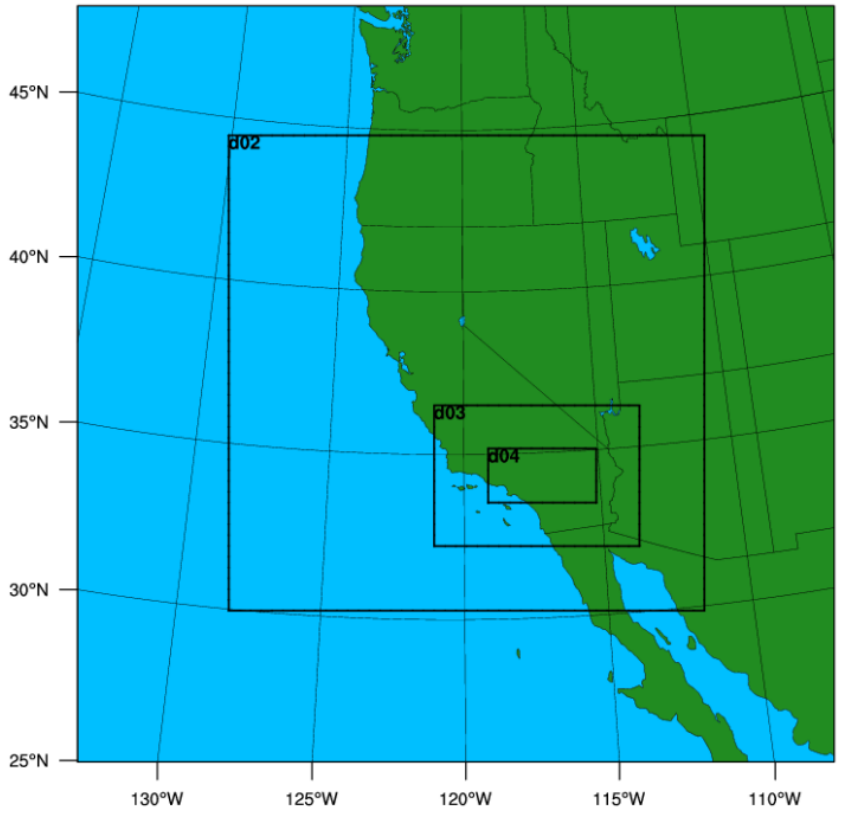
Chemical Transport Modeling Overview

- Computer models are used to simulate meteorology, emissions and air pollutant transformation and transport



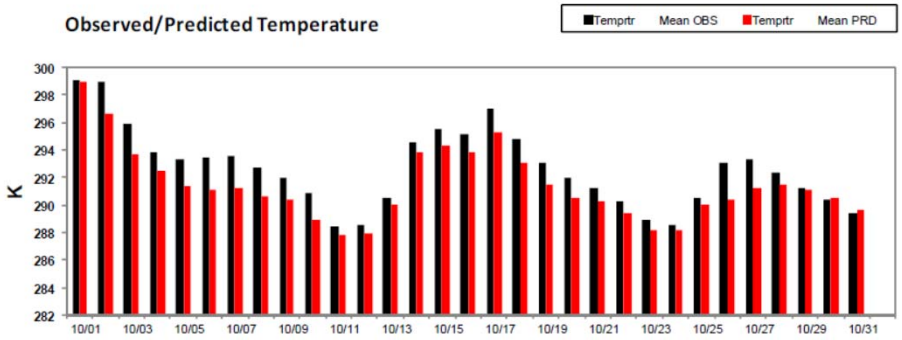
Meteorological Modeling

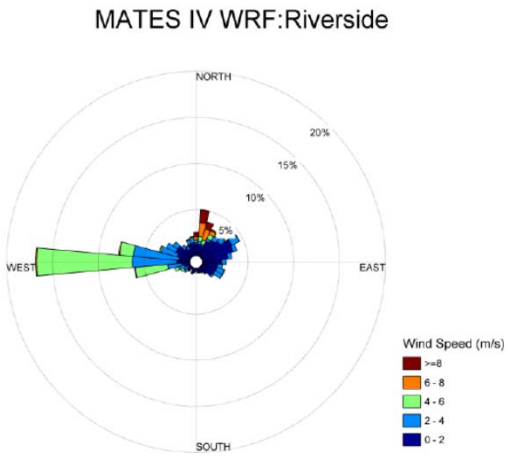
- Use of Weather Forecast Research (WRF) model
  - Calculates meteorological parameters from ground level up to 10 km altitude
  - Four dimensional data assimilation using National Weather Service (NWS) upper-air sounding data and surface measurements
  - National Centers for Environmental Prediction (NCEP) North American Model (NAM) Assimilation Data for model initialization

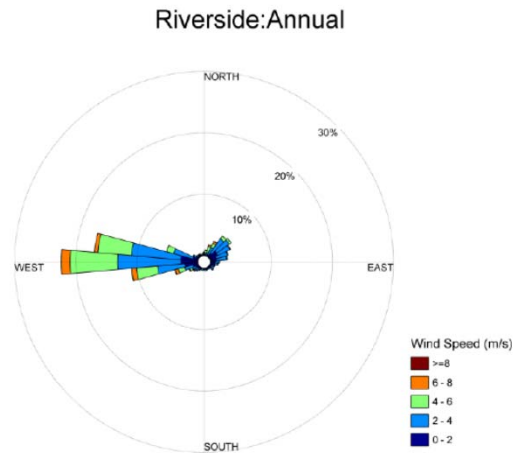


Meteorological Modeling (Cont.)

- WRF modeling results able to capture trends
- Modeling error and biases within acceptable range

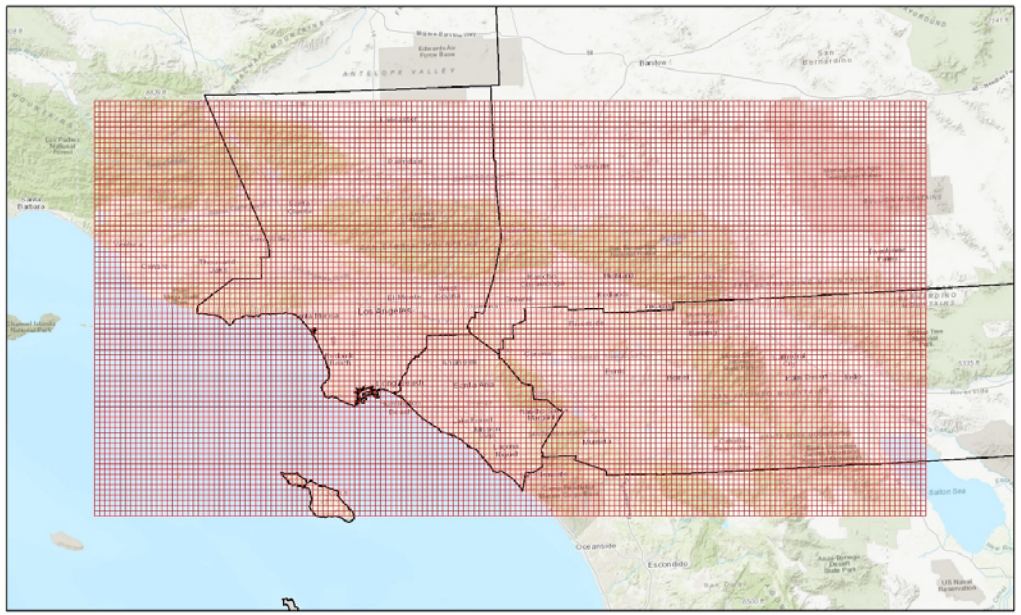






Air Quality Modeling of Toxics

- Air quality modeling is conducted using state-of-the-science chemical transport models
  - The Comprehensive Air Quality Model with Extensions (CAMx) was used for toxics analyses
  - CAMx tracks emissions, dispersion, chemistry, deposition of multiple gas- and particle-phase species
  - Grid resolution is 2 km by 2km



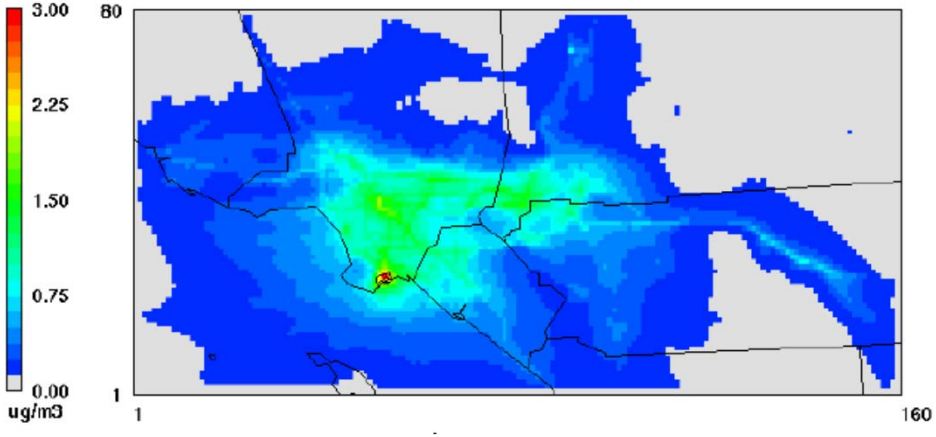
Estimation of Cancer Risk

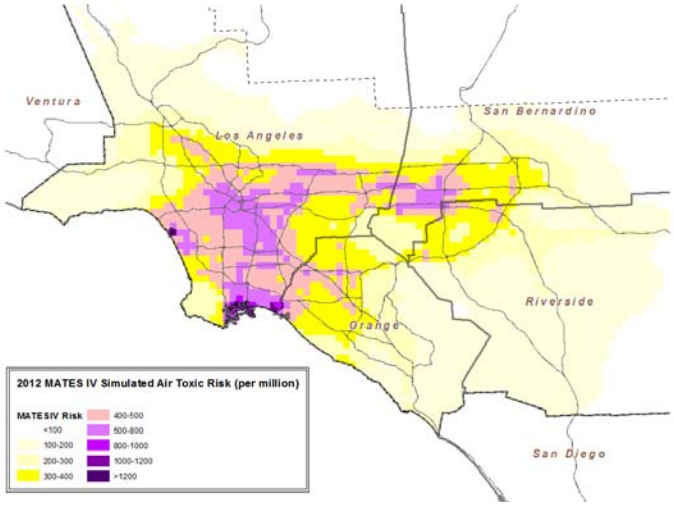
- Calculation of cancer risk with modeled output pollutant concentrations and cancer risk factors for individual toxic pollutants:

$$Risk_{i,j} = \sum_{k} Concentration_{i,j,k} \times Risk\ Factor_{i,j,k}$$

Where i,j are coordinates and k is a given toxic compound

Diesel PM concentration

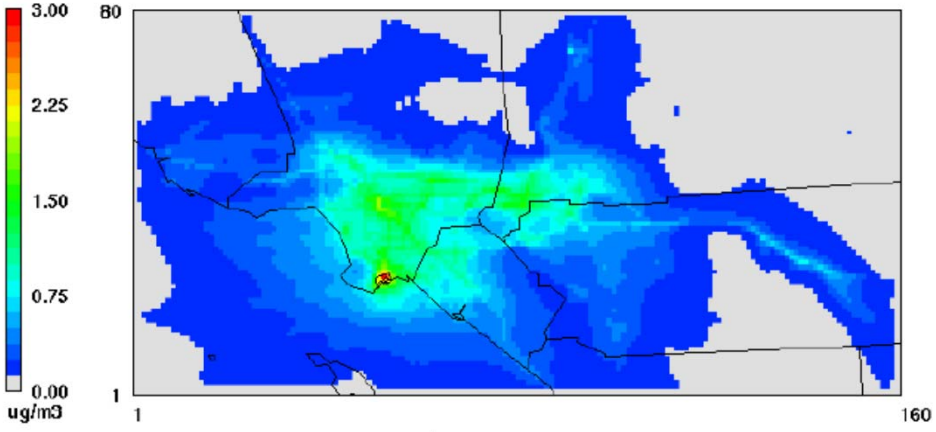


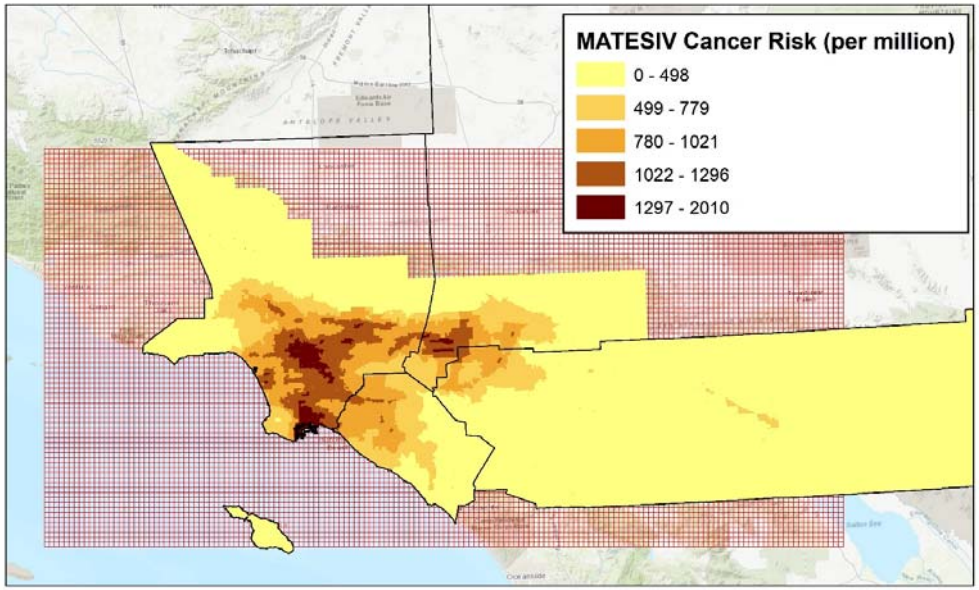


Exposure Analysis

- Output pollutant concentrations are combined with population information to assess potential cancer risk due to exposure to air toxics

Diesel PM concentration





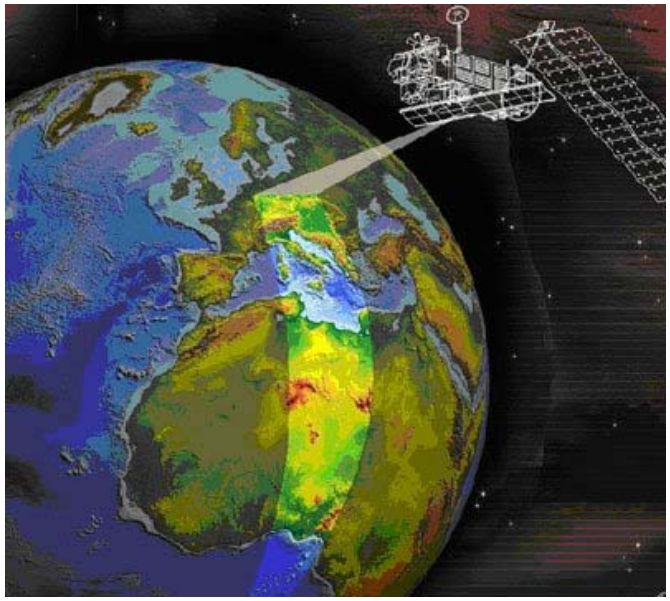
Air Quality Modeling of Criteria Pollutants

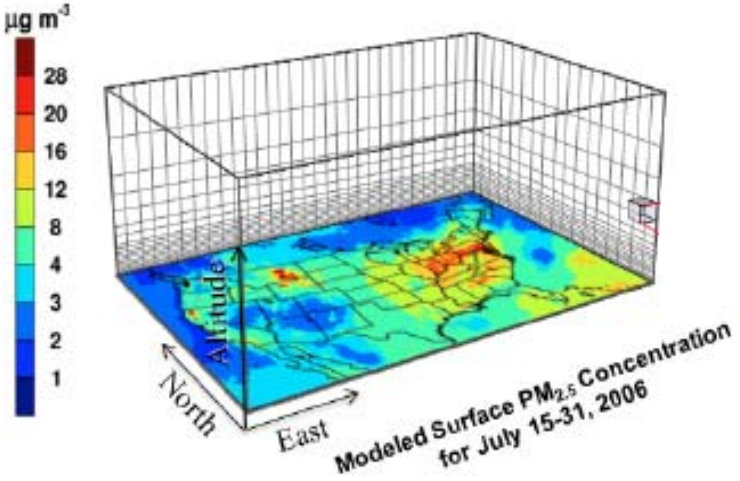
- EPA's recommended Community Multiscale Air Quality (CMAQ) model used in the Air Quality Management Plan (AQMP)
  - CMAQ tracks emissions, dispersion, chemistry, deposition of multiple gas- and particle-phase species
  - Grid resolution is 4 km by 4km
  - Requires background criteria pollutant concentrations, from global models (MOZART) and satellite measurements

Future Improvements: Assimilating Satellite Data

Jet Propulsion Laboratory
California Institute of Technology

- Assimilating Satellite Data into Global Chemical Transport model, GEOS-CHEM to evaluate inter-continental scale transport
- Collaboration with NASA JPL and UC Riverside





Questions

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