

WRAP Mobile Source Emission Inventories

Presented at
**WRAP Regional Haze Emissions Inventories
"Lessons Learned" Workshop**

**Salt Lake City, Utah
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Presentation Overview

- Emission inventory objectives
- On-road vehicle emission inventories
- Nonroad emission inventories
 - Traditional nonroad equipment
 - Locomotives
 - Aircraft
- Commercial marine emission inventories
- Road dust emission inventories

Overall Objectives for Developing Mobile Source Emissions

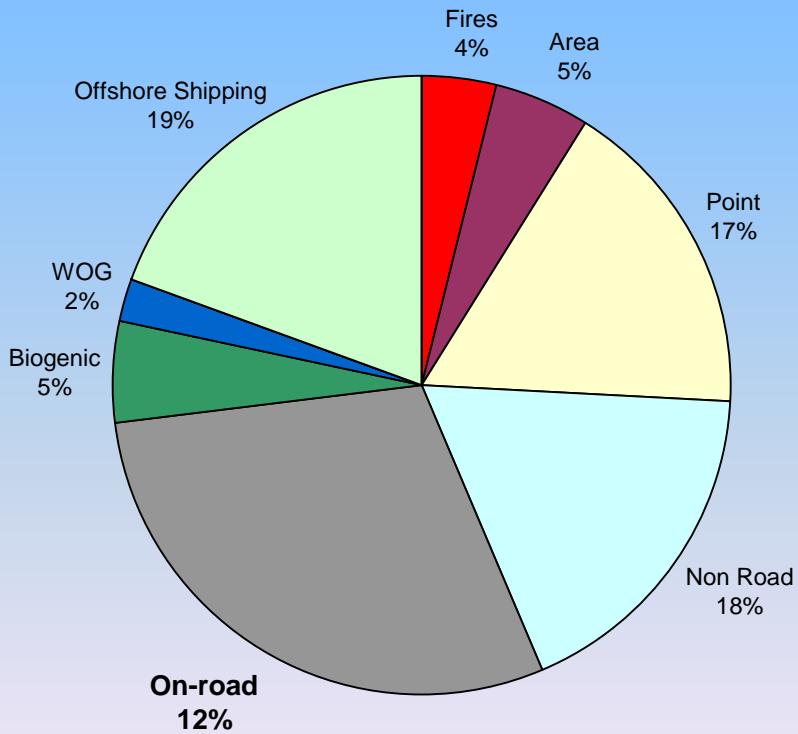
- Develop up-to date and accurate mobile source emission inventories for WRAP states
- Use consistent emissions estimation methods across states
- Obtain up-to-date modeling and activity inputs from state and local agencies

Mobile Source Emissions Inventory Scope

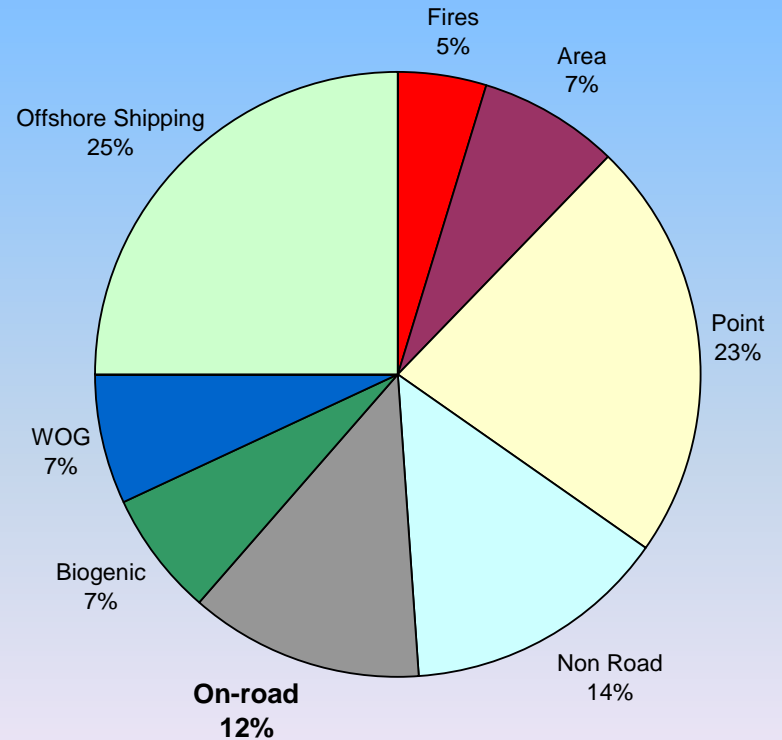
- Temporal resolution: 2002 base year, 2008/2013/2018 future years, seasonal
- Geographic resolution: Western states and tribes, county level
- Pollutants: NO_x, SO₂, VOC, CO, PM₁₀, PM_{2.5}, NH₃

On-Road Emissions

WRAP Total NOx Emissions Plan02b



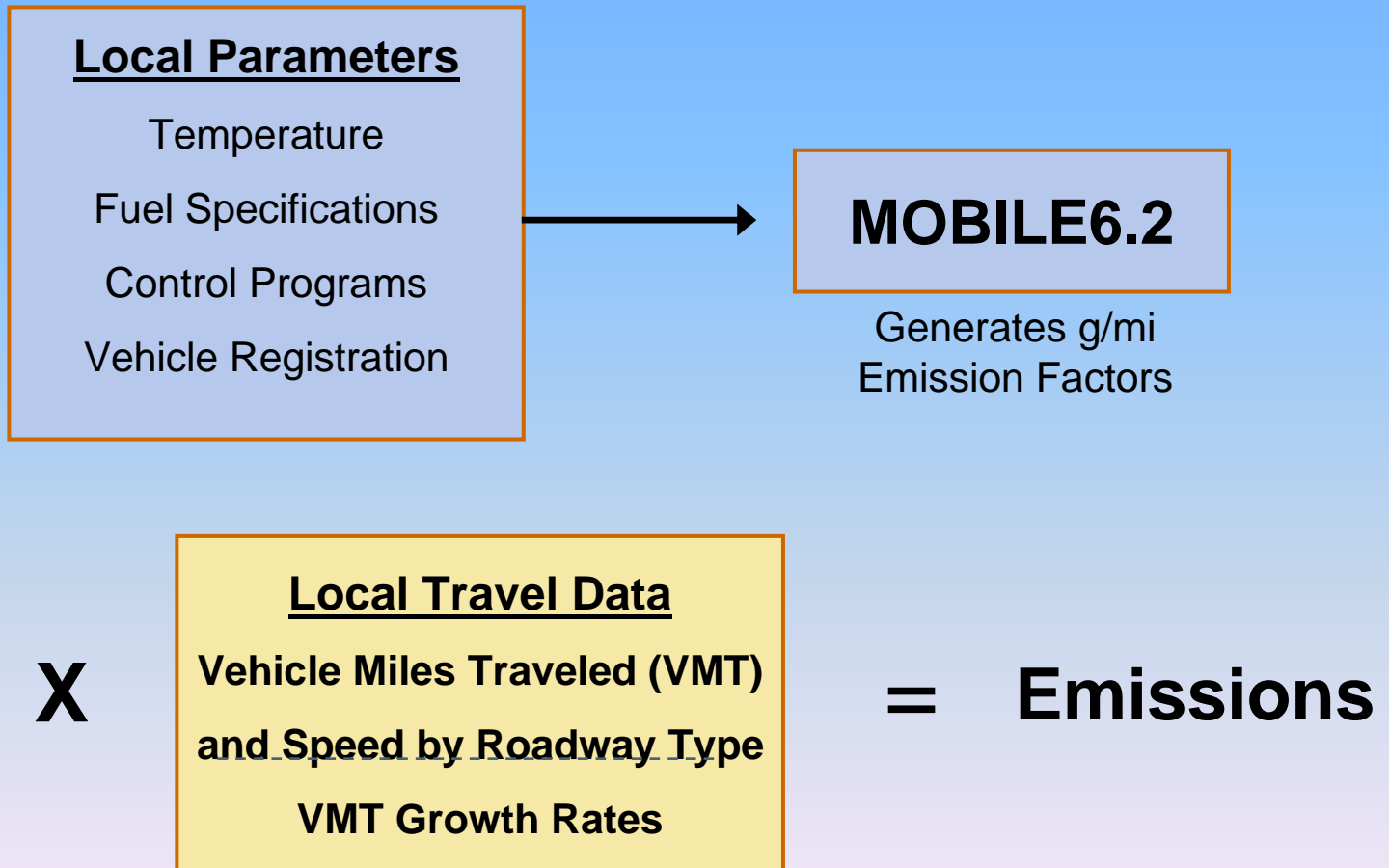
WRAP Total NOx Emissions Base 18b



On-Road Vehicle Categories

- Light-duty gasoline vehicles
 - cars, light-duty trucks, motorcycles
- Heavy-duty gasoline trucks
- Light-duty diesel vehicles
 - cars, light-duty trucks
- Heavy-duty diesel trucks

On-Road Mobile Sources Methodology



Surveys of State/Local Agencies for Modeling Inputs and VMT Data (for on-road and non-road emissions)

- Survey for modeling inputs and VMT
 - Default model inputs and VMT from EPA data base used for NEI2002, Sierra Research analysis of fuel survey data, previous WRAP mobile source emissions work
 - Detailed spreadsheets were posted to web
 - Responses were received from all state agencies and key local agencies

EPA MOBILE6 On-Road Emission Factor Model

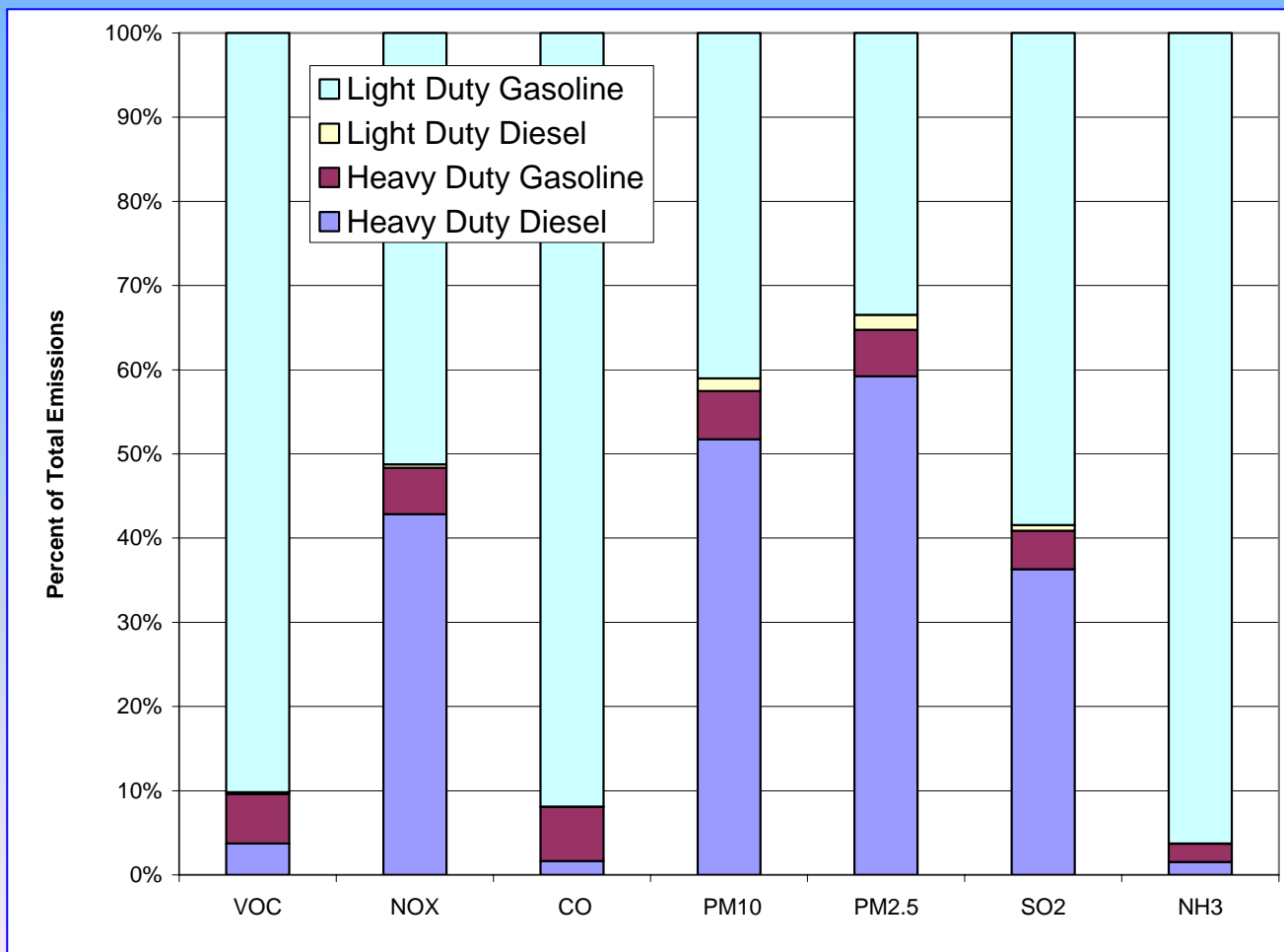
- Incorporates all “on the books” Federal motor vehicle control programs
 - Tier 1 light-duty vehicle standards (begins MY 1996)
 - National Low Emission Vehicle (NLEV) standards (begins MY 2001)
 - Tier 2 light-duty vehicle standards (begins MY 2005), with low sulfur gasoline beginning summer 2004
 - Heavy-duty vehicle standards (begins MY 2004)
 - Heavy-duty vehicle standards (begins MY 2007), with low sulfur diesel beginning with summer 2006
- Models state/local control programs
 - Fuels regulations
 - Inspection and Maintenance programs

California On-Road Emissions

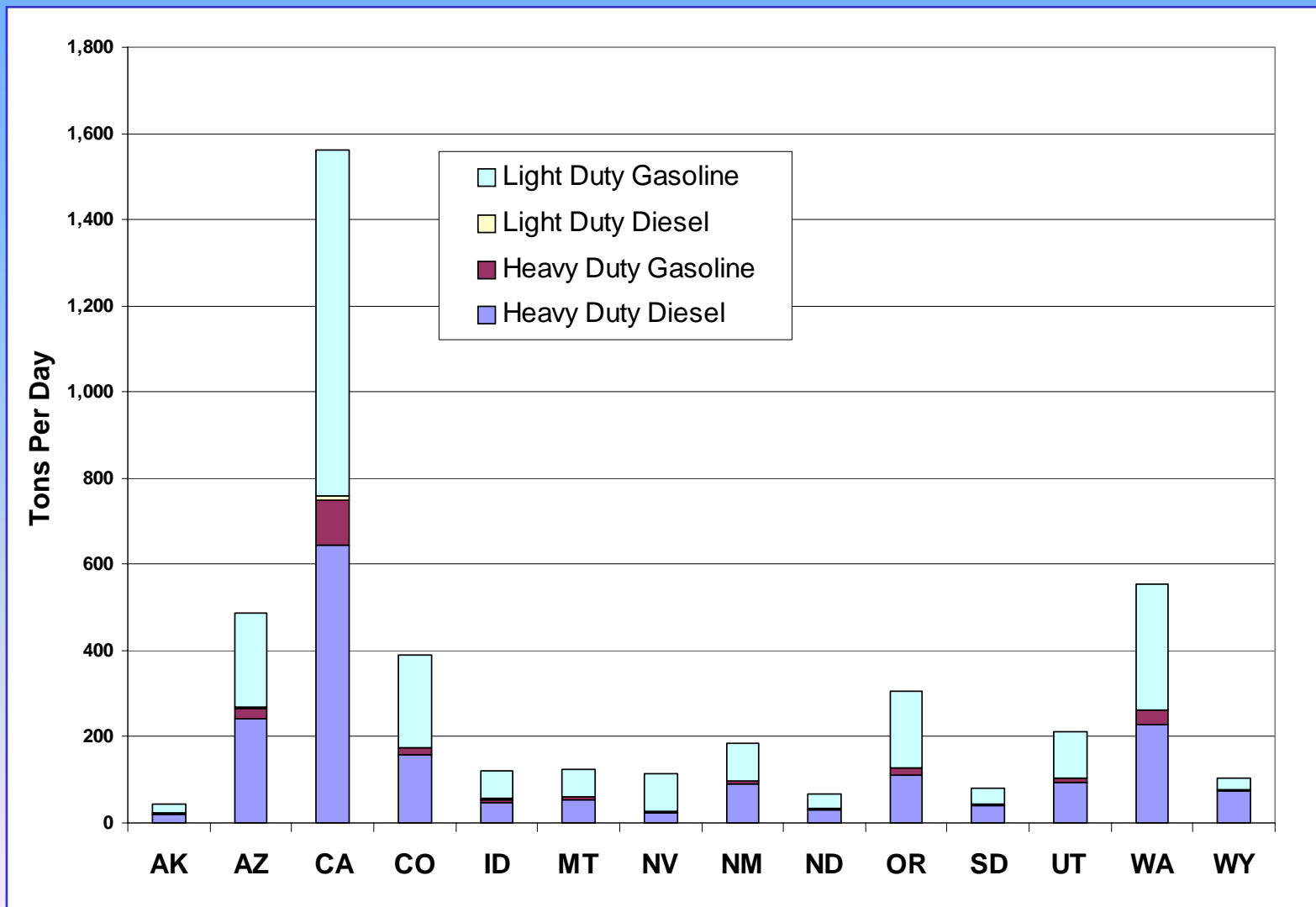
- California Air Resources Board (CARB) has developed CA-specific EMFAC model
- EMFAC includes both emission factors and VMT
- In fall 2005 CARB provided emissions from internal working version of EMFAC (which was being updated)
- EMFAC2007 was released in late 2006
- On-road emissions have just been estimated using EMFAC2007; CARB is reviewing

2002 Western States Average Annual On-Road Emissions

(% contribution by vehicle class and fuel type)



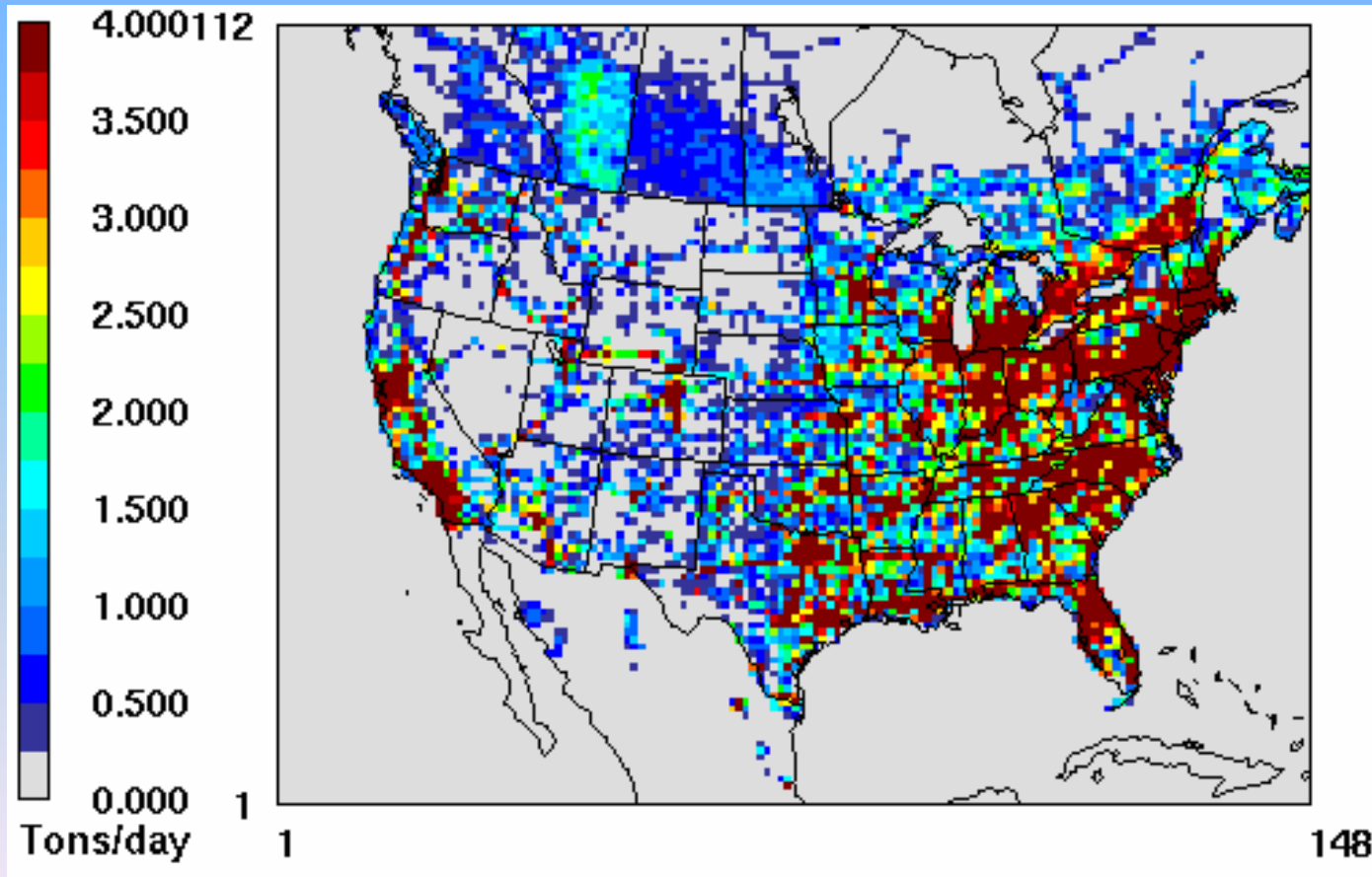
2002 Western States Average Annual On-Road NOx Emissions



CA emissions are from Oct 2005 and are now being updated

Spatial Distribution of 2002 All RPO On-Road NO_x Emissions (July Weekday)

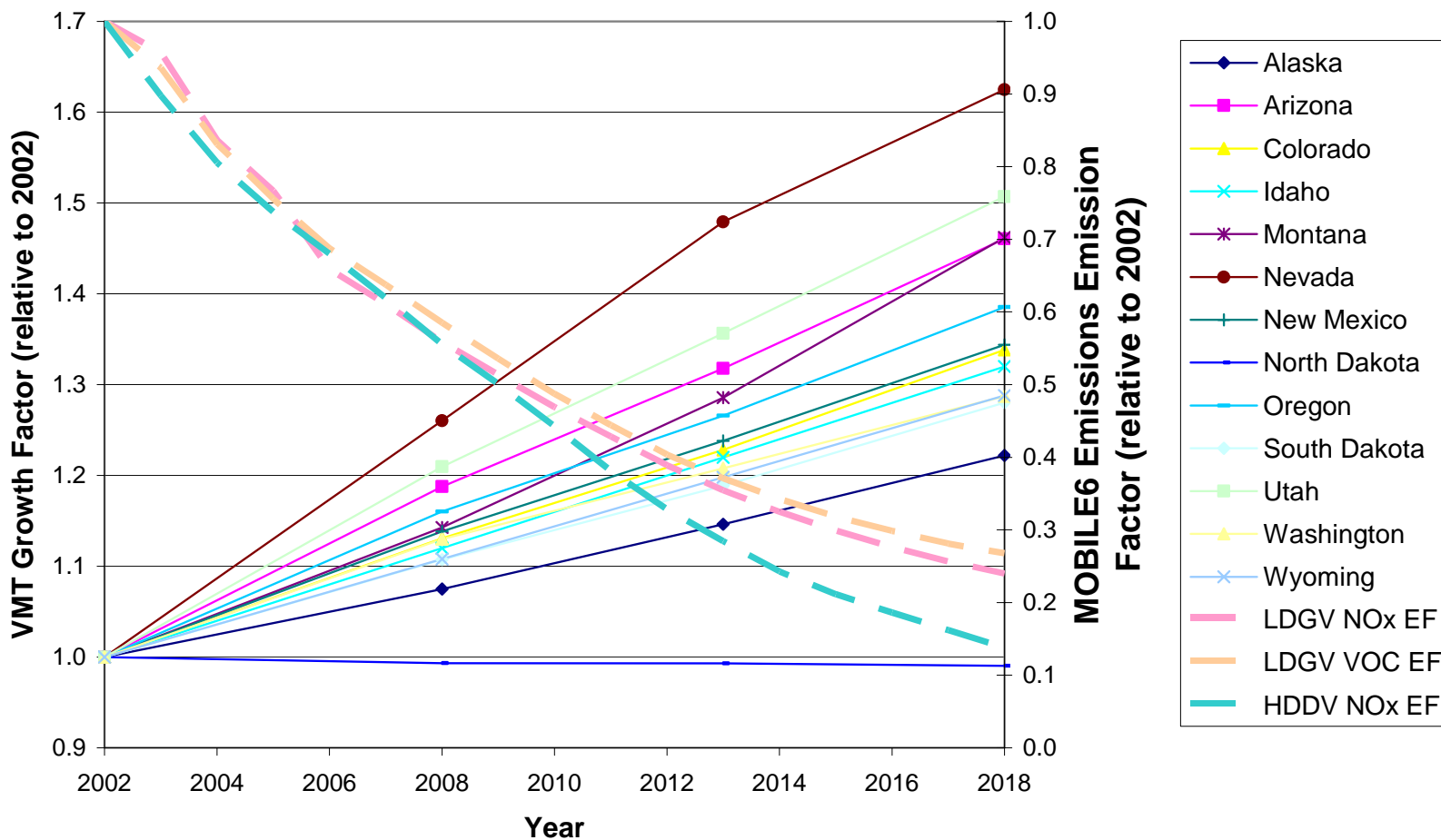
(Includes Fall 2005 CA emissions; now being updated)



State VMT Growth and MOBILE6 Emission Factor Reductions Relative to 2002

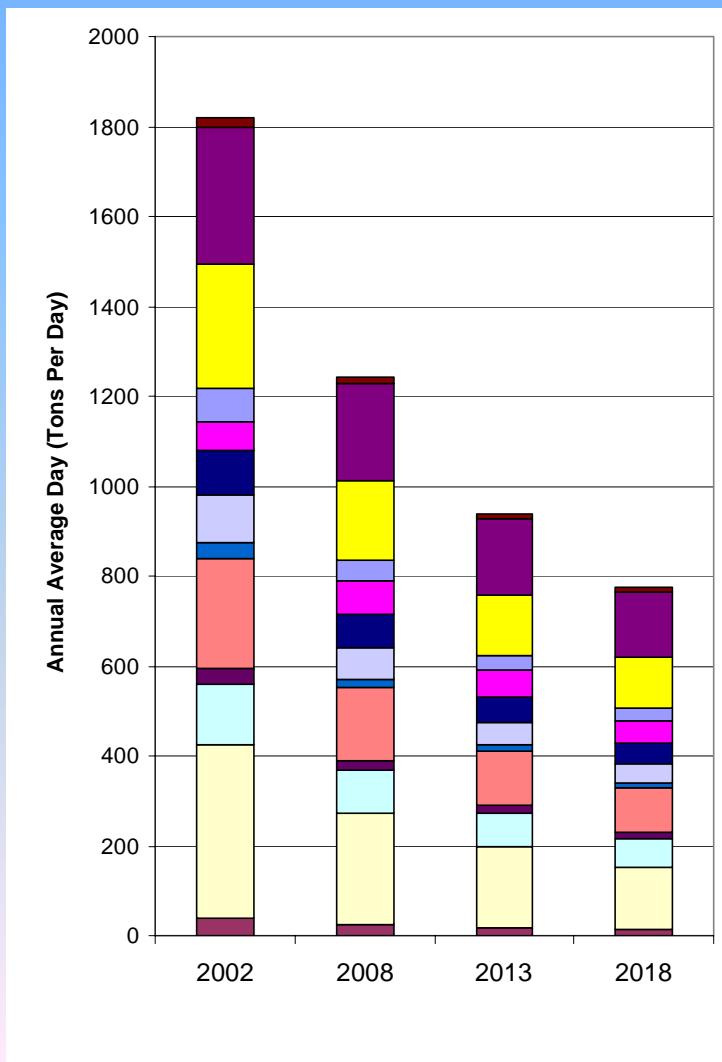
WRAP State VMT Growth Factors and MOBILE6 Estimated Fleet Turnover Effects*

*Based on MOBILE6 run with default fleet characteristics, RVP=8 psi, min temp=60F, and max temp=84F

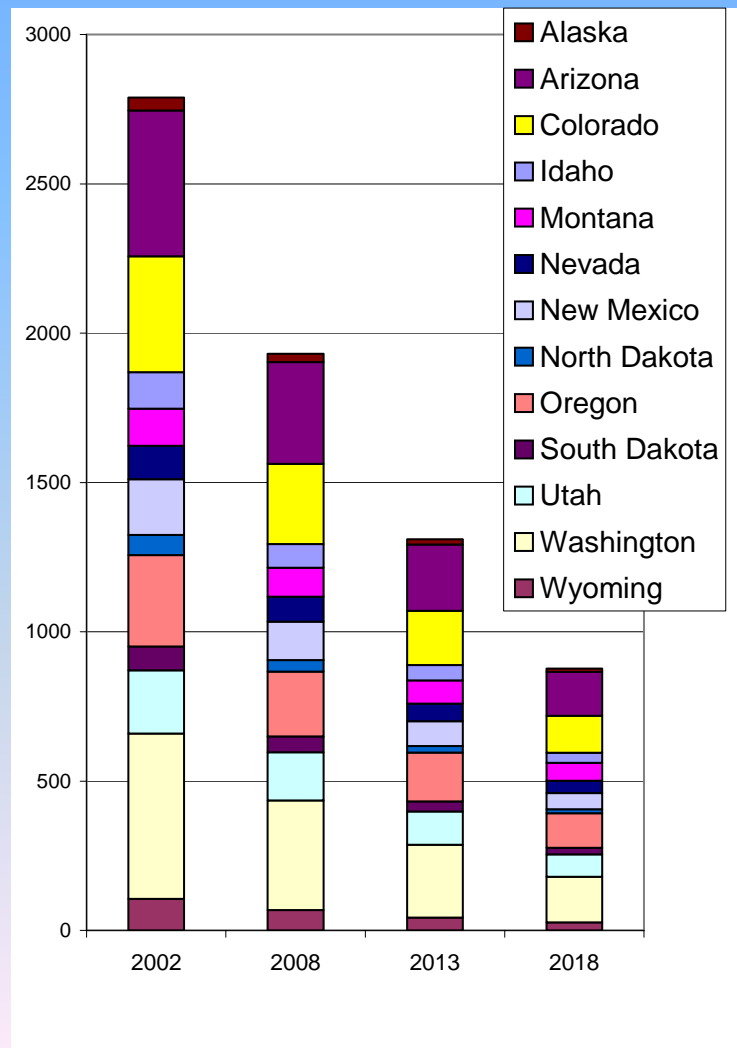


Western States Average Annual On-Road VOC and NOx Emissions by State (excludes CA)

VOC

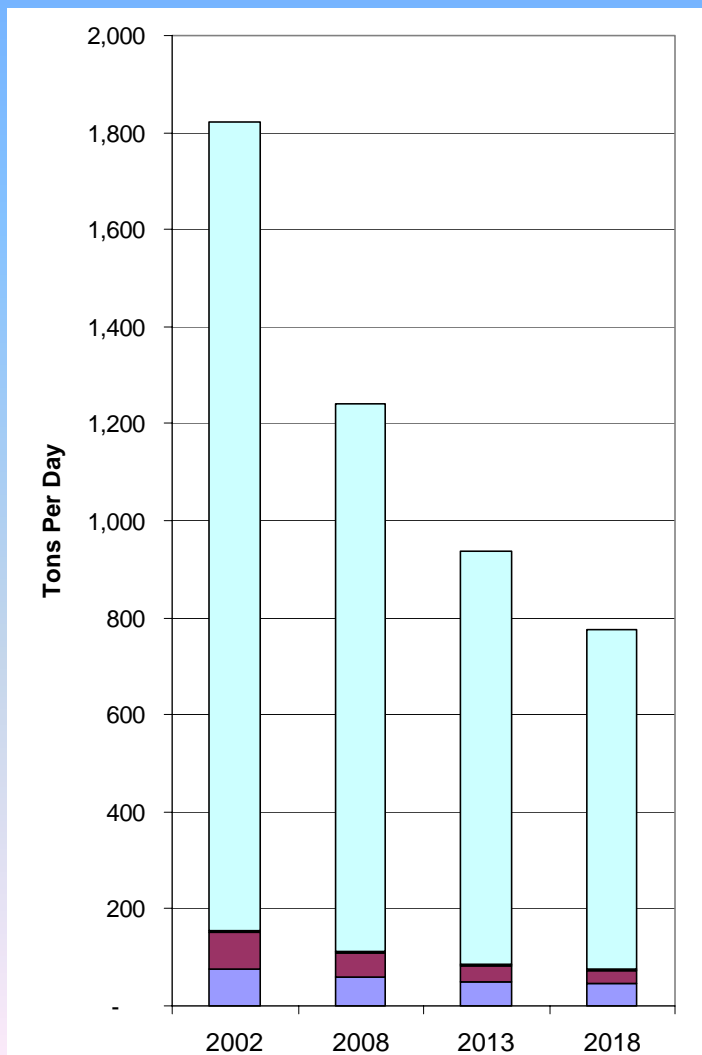


NOx

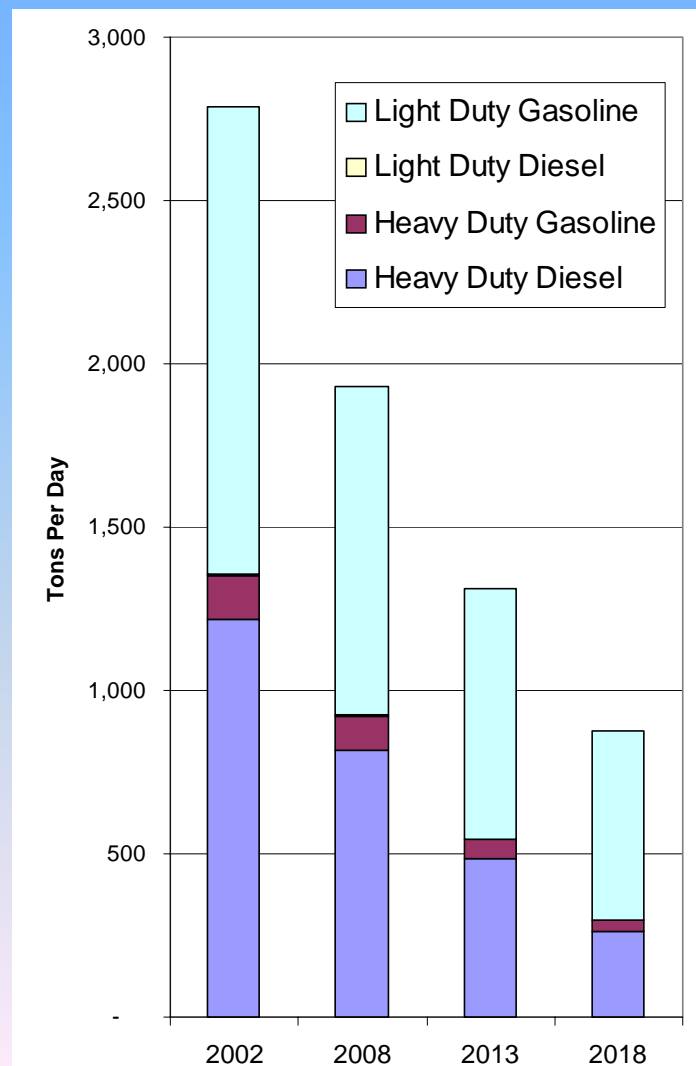


WRAP States Average Annual On-Road VOC and NOx Emissions by Class (excludes CA)

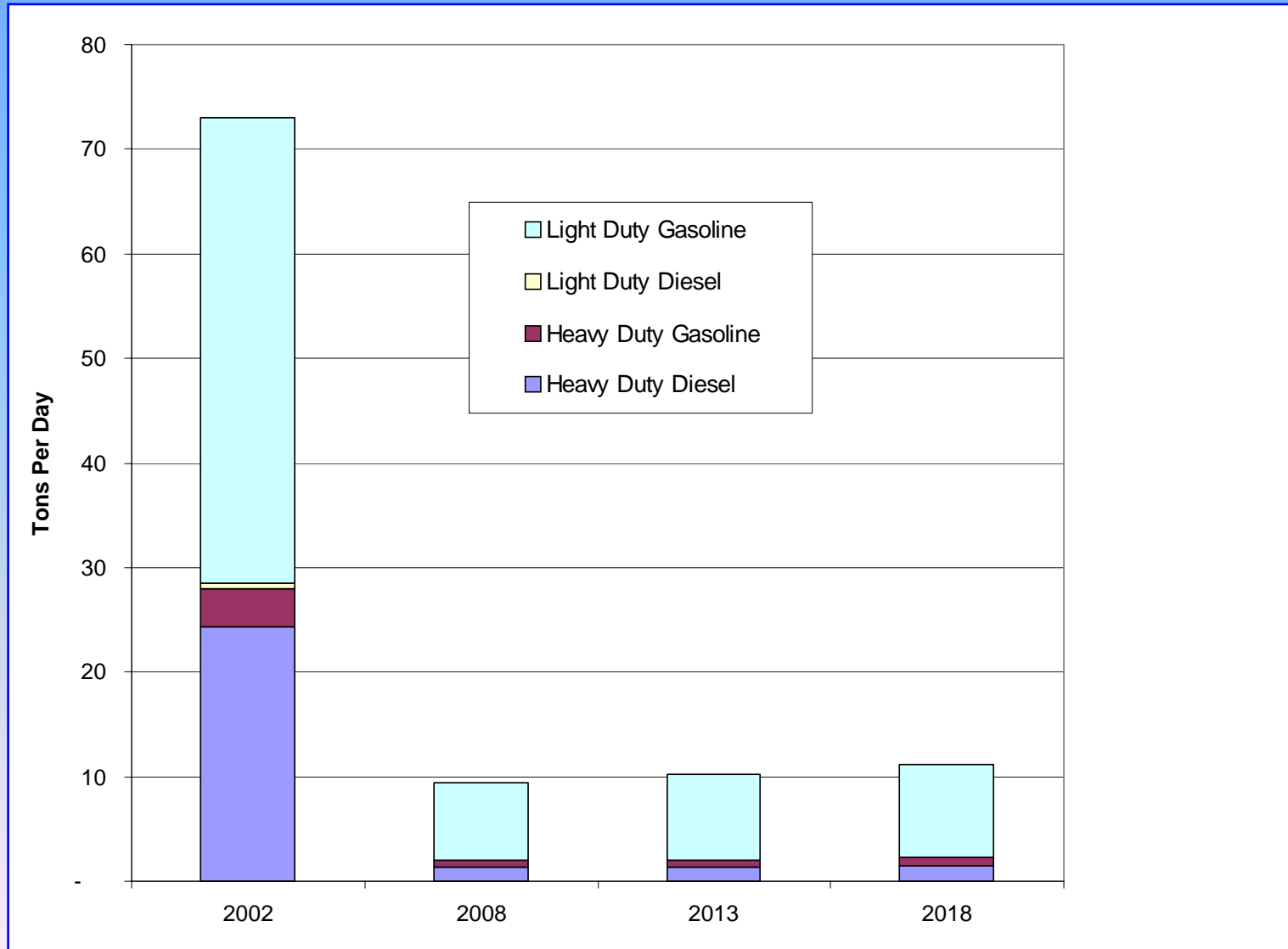
VOC



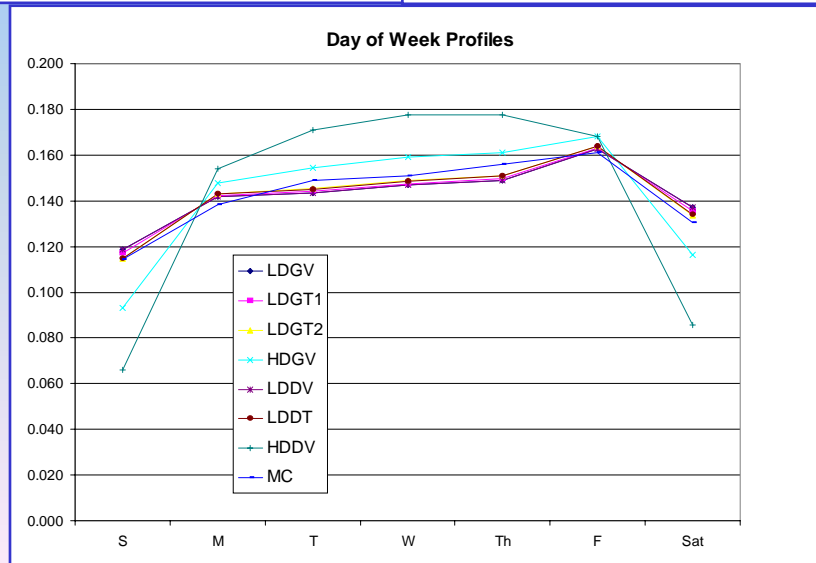
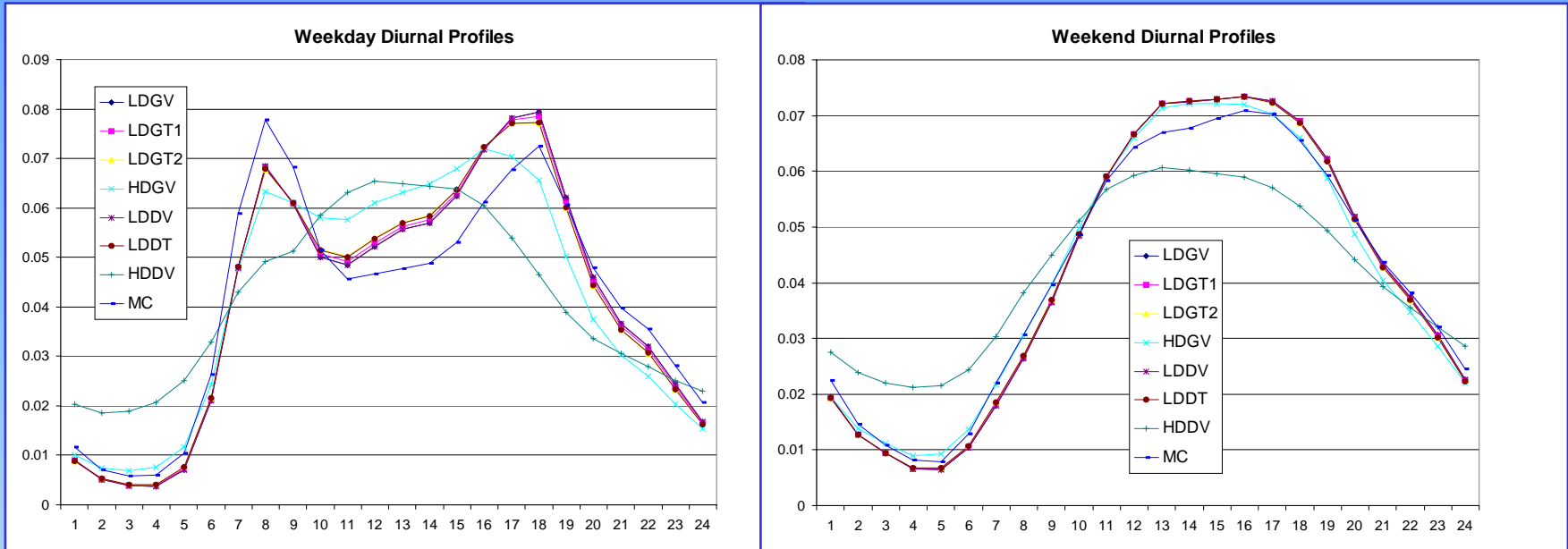
NOx



WRAP States Average Annual On-Road SO₂ Emissions by Class (excludes CA)



Updated On-Road Mobile Temporal Profiles

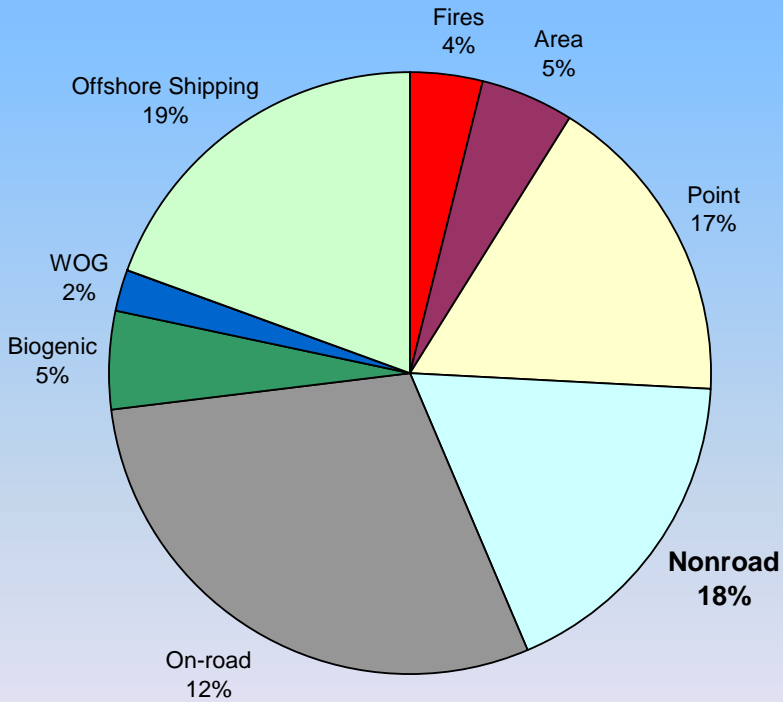


Key Points for Future Development of On-Road Inventories

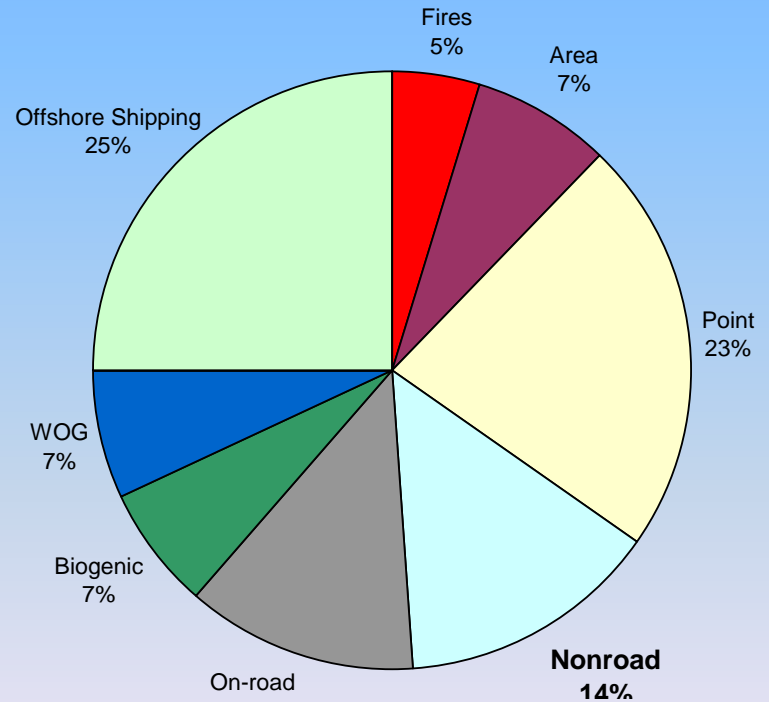
- EPA NMIM model, under development when the project was underway, is now complete and available for generating state and county on-road and off-road emission inventories.
<http://www.epa.gov/otaq/nmim.htm>
- Key is to obtain accurate estimates of VMT and modeling inputs – provide county-level updates to EPA for NMIM database

Non-Road Emissions

WRAP Total NOx Emissions Plan02b



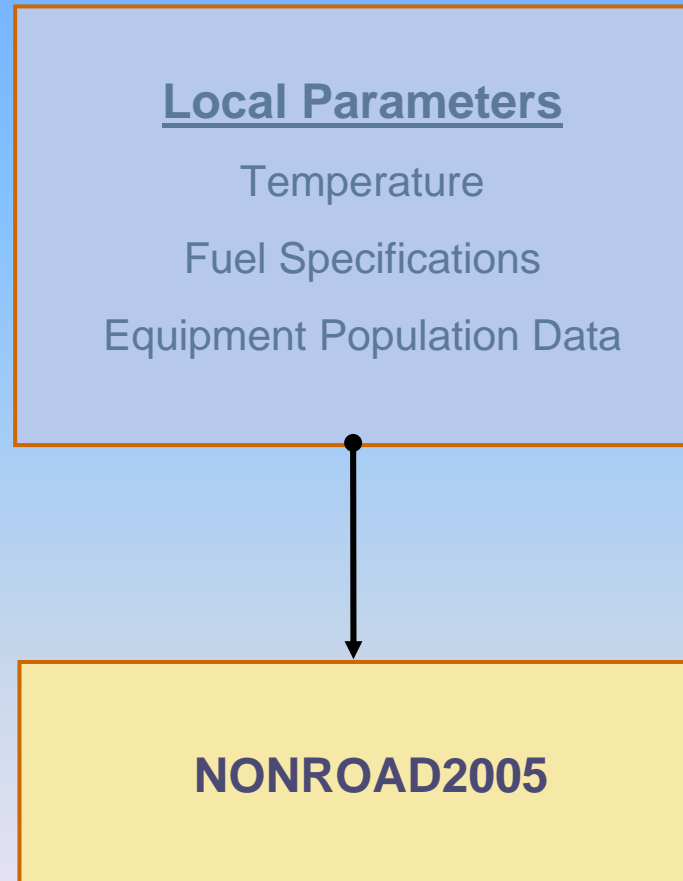
WRAP Total NOx Emissions Base 18b



Non-Road Equipment Categories

- Agricultural Equipment
- Aircraft
- Airport Ground Support Equipment
- Commercial Equipment
- Commercial Marine
- Construction and Mining Equipment
- Industrial Equipment
- Lawn and Garden Equipment
- Locomotives
- Logging Equipment
- Oil Field Equipment
- Pleasure Craft
- Railroad Equipment
- Recreational Equipment

Modeling Traditional Non-Road Sources



California has its own OFFROAD model.

EPA NONROAD Emissions Model

- Estimates total emissions — includes both emission factors and activity data
- Emissions from traditional nonroad sources
- Includes defaults for all activity data
- Includes all “on the books” Federal control programs
 - Tier 1 through Tier 4 CI engines >50 hp
 - Tier 1 and Tier 2 CI engines <50 hp
 - Phase 1 and 2 SI engines <25 hp
 - Tier 1 and Tier 2 large SI engines >25 hp
 - Recreational vehicles
 - Recreational marine SI
 - Recreational marine CI >50 hp
- Estimates future year emissions with population growth and fleet turnover to new standards

NONROAD Model Emissions Estimates

For each type of equipment

$$\begin{aligned} \text{Emissions} &= \text{Equipment population} \\ &\times \text{Average load factor} \\ &\times \text{Activity (hours of use per year)} \\ &\times \text{Emission factor} \end{aligned}$$

by age, horsepower, fuel type

NONROAD has assumptions and default values for all calculation inputs

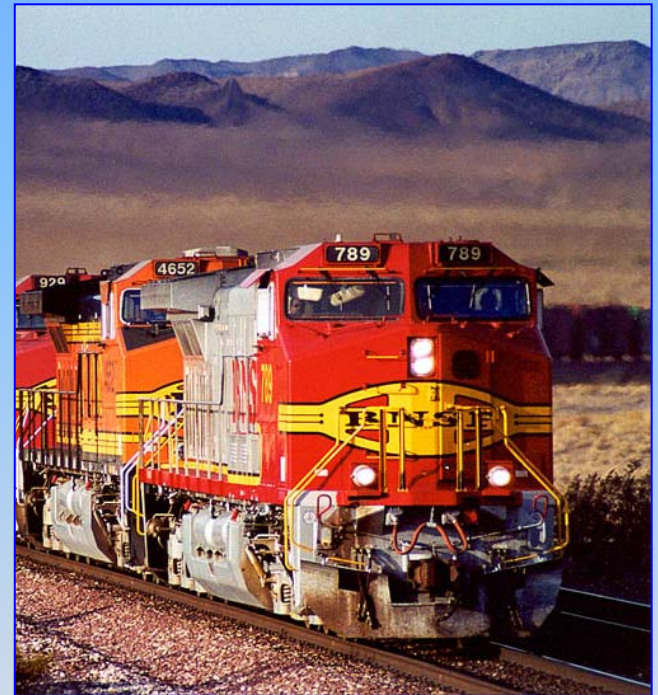
Surveys of State/Local Agencies for NONROAD Modeling Inputs

- Surveyed state and local agencies for base and future years NONROAD fuel and met inputs, fuels control programs, and also requested any available equipment population data.
 - Responses received from all state agencies and key local agencies
 - Very little local equipment population data available
- CARB provided emissions estimates from their OFFROAD model and internal files

Locomotive Emissions

Railroad types estimated

- Class I railroads: UP and BNSF in Western States
- Class II/III (smaller regional railroads)



2002 Locomotive Emissions Methodology

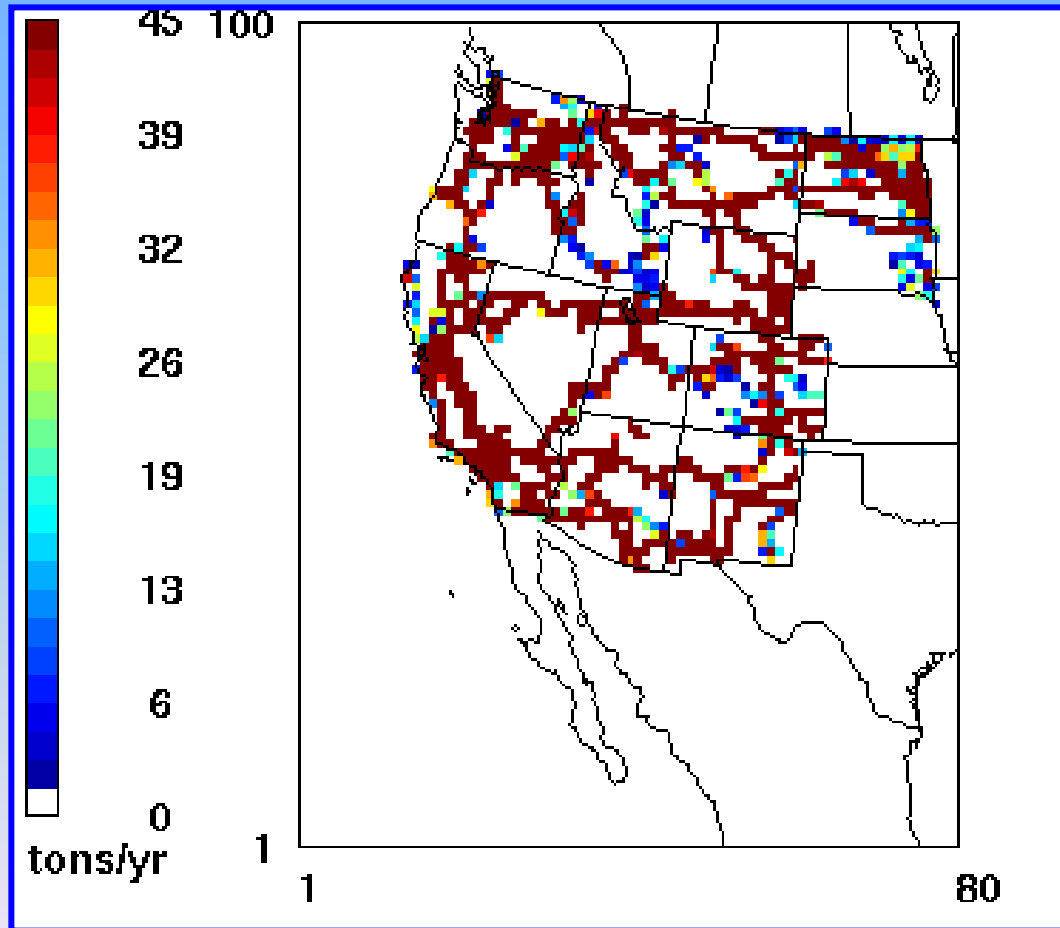
- Obtained 2002 national fuel consumption data
- Allocated fuel consumption to counties using historical freight data
- Estimated county-level emissions as:

County emissions = (county fuel consumption) x (emission factor)

Locomotive Emissions Data Sources

Data	Source
Fuel consumption	<ul style="list-style-type: none">▪ Class I - Association of American Railroads (AAR, 2003)▪ Class II/III - American Short Line & Regional Railroad Association
Historic freight movements (allocation surrogate)	Bureau of Transportation Statistics
Emission factors (emissions/gal)	EPA
2002 Locomotive emissions provided by agencies	Alaska; Arizona; Clark County, NV; Idaho; Wyoming

2002 Locomotive NOx Emissions



Locomotive Emissions Projections

- Fuel consumption projected from historical trends in national freight ton-miles/year and freight company efficiency
- Emission factors reduced to adjust for fleet turnover using EPA analysis, including use of ultra low sulfur fuel (15 ppm) in 2012

Aircraft Emissions

Aircraft types:

- Air carriers – larger turbine-powered commercial aircraft with at least 60 seats or 18,000 lbs payload capacity
- Air taxis – commercial turbine or piston-powered aircraft with less than 60 seats or 18,000 lbs payload capacity
- General aviation – small piston-powered, non-commercial aircraft
- Military aircraft

Aircraft activity data is landings and takeoffs (LTOs)



2002 Aircraft Emissions Methodology

- Emissions = LTOs * emission factor/LTO
- Based on EPA NEI2002 aircraft emissions estimates 1285 airports total in the Western States
- Emissions for 549 towered airports:
 - FAA Emissions and Dispersion Modeling System (EDMS), using detailed activity data by airframe for Air Carriers and Air Taxis
 - Fleet average emission factors for air taxis and general aviation, multiplied by total LTOs
- Smaller airports: fleet average emission factors
- Substituted aircraft emissions estimates available from other studies: Alaska (WRAP project), Wyoming, Arizona, Idaho, Clark County

Aircraft Emissions Projections

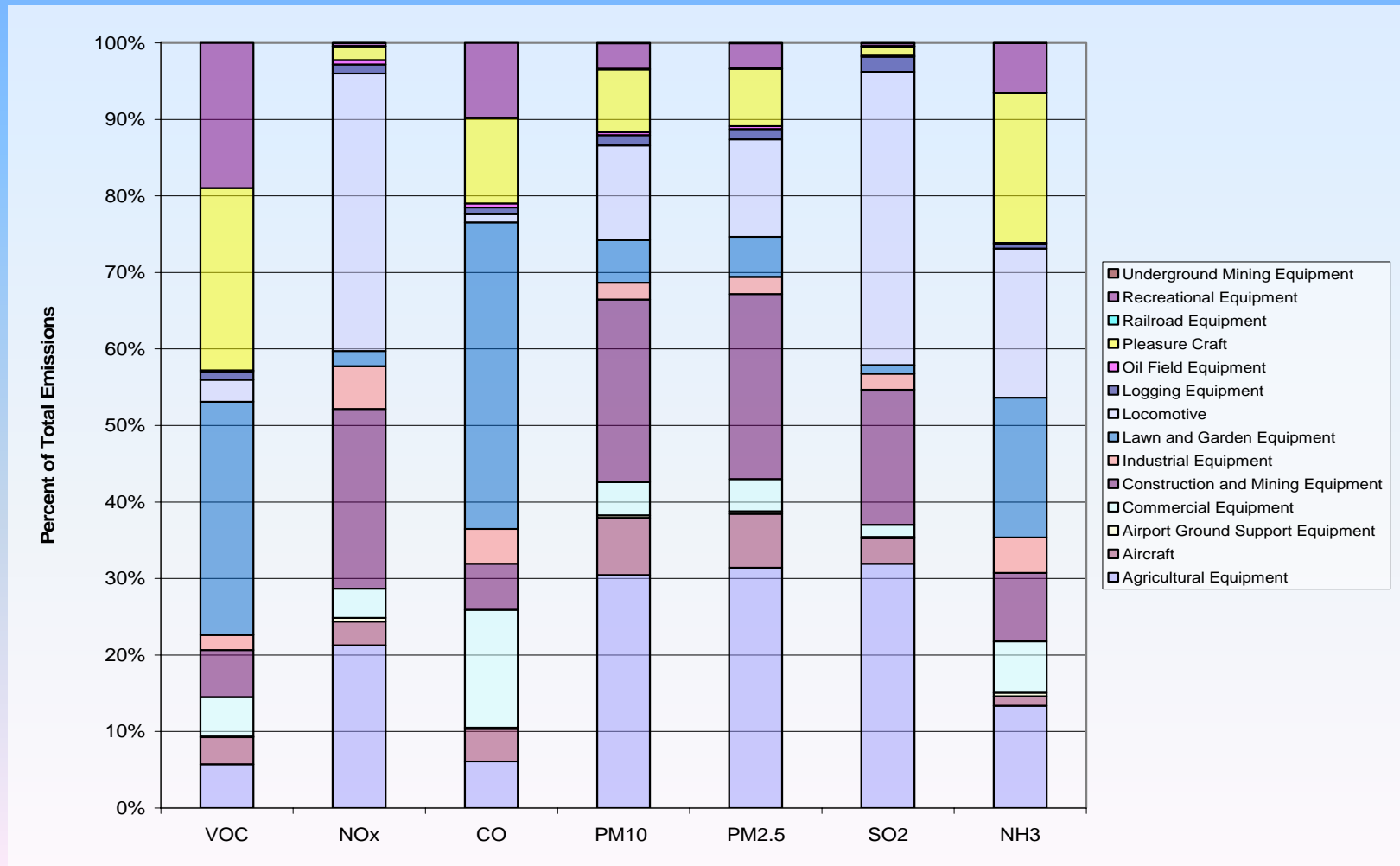
- Obtained Federal Aviation Agency LTO projections by airport and aircraft category
- Emissions increase in proportion to LTO increase (or decrease) as there are no emissions standards/factors changes

California Non-Road Emissions

- California has developed CA-specific OFFROAD model for traditional nonroad sources; model was released in late 2006
- OFFROAD does not include all traditional nonroad equipment, nor does it include all CARB “on the books” regulations
- In fall 2005 CARB provided emissions from internal working version of OFFROAD
- CARB has just provided updated OFFROAD, locomotive, and aircraft emissions; ENVIRON has processed, and CARB is reviewing

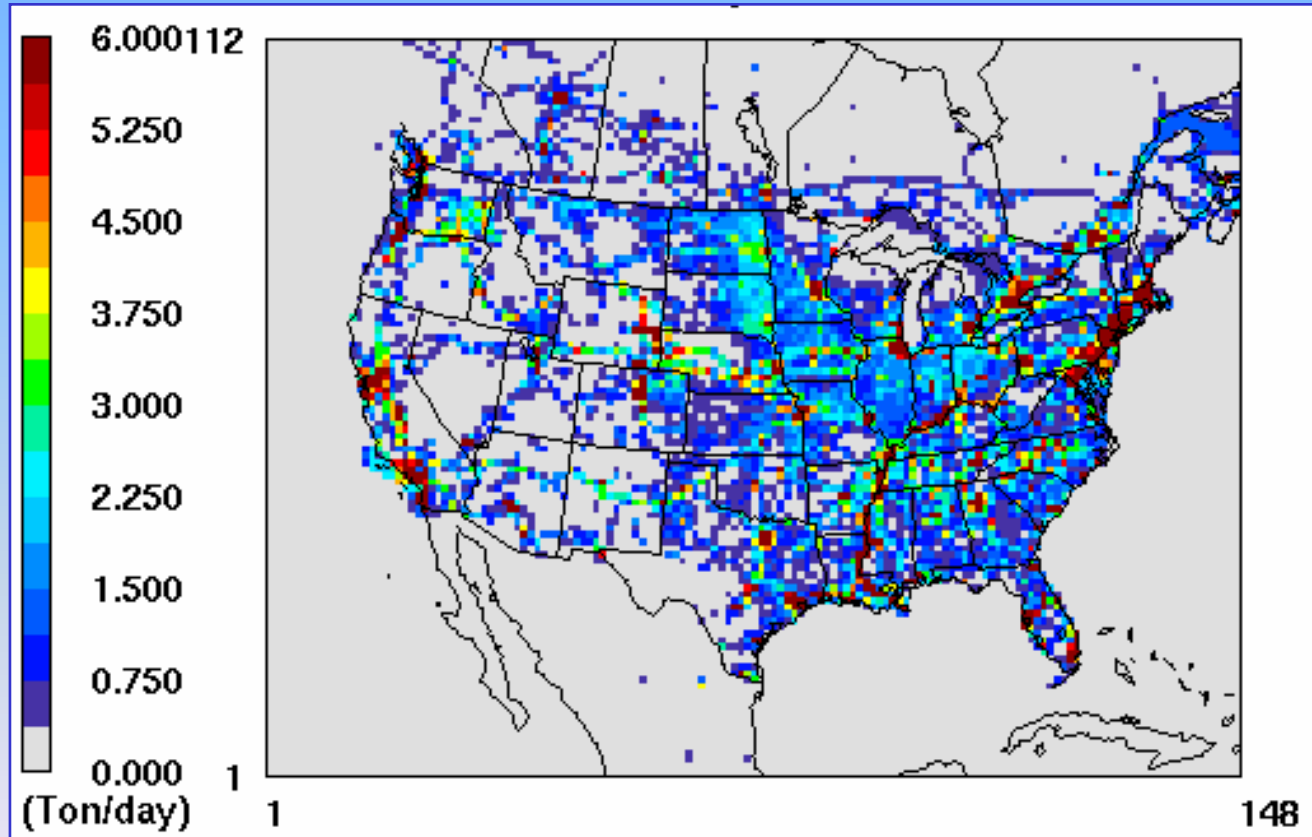
2002 Western States Average Annual Non-Road Emissions

(% contribution by source category)



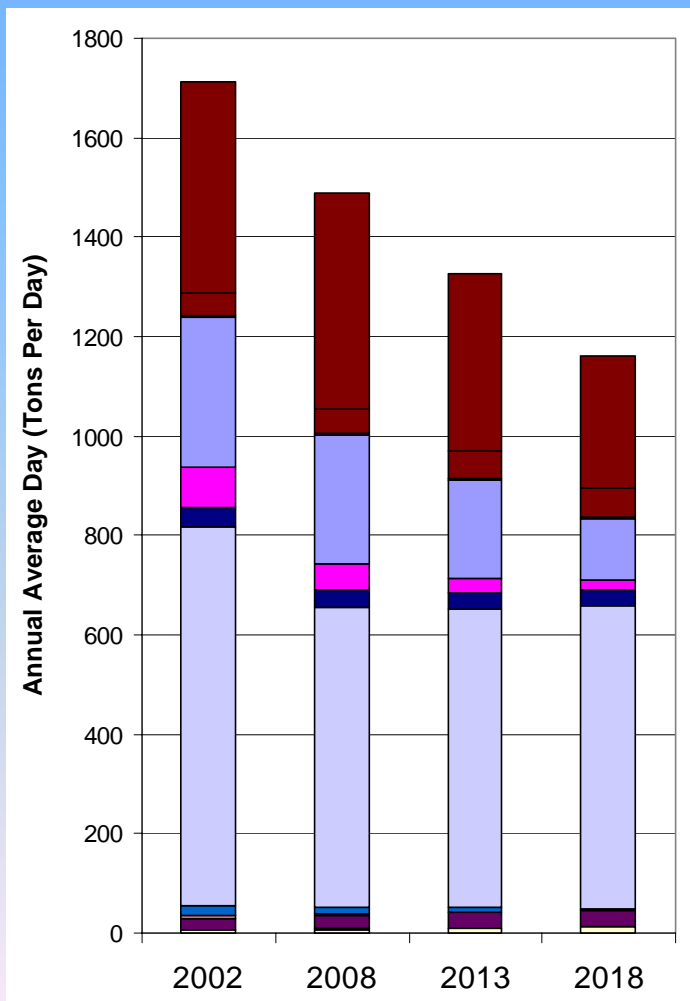
Spatial Distribution of 2002 All RPO Non-Road NOx Emissions (July Weekday)

(includes Fall 2005 CA emissions, now being updated)

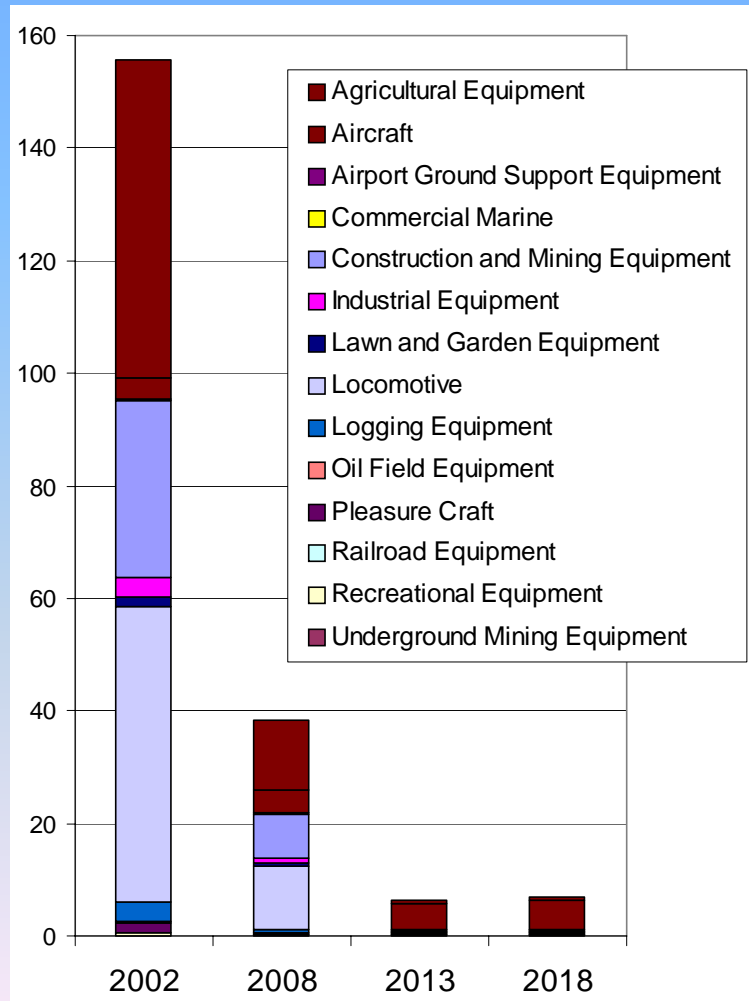


Western States Average Annual Non-Road NOx and SO₂ Emissions by Category (excludes CA)

NOx



SO₂



- Agricultural Equipment
- Aircraft
- Airport Ground Support Equipment
- Commercial Marine
- Construction and Mining Equipment
- Industrial Equipment
- Lawn and Garden Equipment
- Locomotive
- Logging Equipment
- Oil Field Equipment
- Pleasure Craft
- Railroad Equipment
- Recreational Equipment
- Underground Mining Equipment

Key Points for Future Development of Non-Road Inventories

- EPA NMIM model, under development when the project was underway, is now complete and available for generating state and county on-road and off-road emission inventories.
<http://www.epa.gov/otaq/nmim.htm>
- New FAA EDMS model was released after NEI2002 and WRAP aircraft emissions were estimated; latest model includes PM emission factors not in previous version
- California has developed detailed activity data for each major rail yards in the state using detailed activity data for each facility and time-in-mode emissions calculations for health risk assessments (<http://www.arb.ca.gov/railyard/hra/hra.htm>)
- Incorporate new locomotive regulations when finalized

Proposed Federal Locomotive Emissions Standards

- EPA proposed new Tier 3/4 standards for locomotives in March 2007
- EPA estimated national emissions reductions
- EPA's analysis applied to Western States:

Western States Total Locomotive Emissions (tons)					
	VOC	NOx	CO	PM	SO2
2002	43	963	116	26	69
2018	45	741	156	26	1
% Change	4%	-23%	34%	-1%	-99%
Proposed Locomotive Rule Changes in Western States, 2018					
% Change	-38%	-13%	0%	-33%	0%
Reduction (tons)	(17)	(94)	-	(8)	-



Commercial Marine Vessels (CMV)

Source types:

- Ocean-going vessels (OGV), large deep draft vessels
- Tugs and tow boats (Coast, Inland Waters, and Rivers)
- Ferries
- Support, excursion, and dredges
- Commercial fishing
- Military





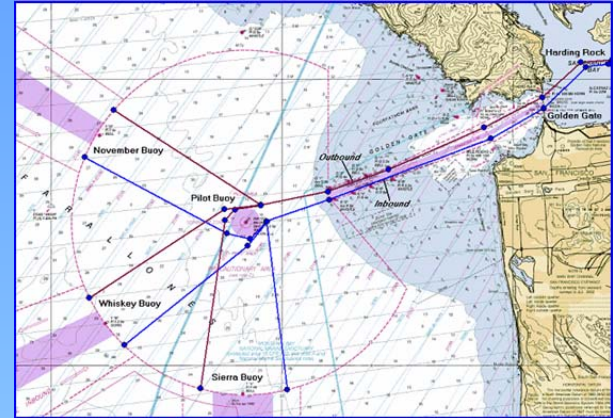
EPA CMV Engine Categories

- $\Rightarrow 30$ l/cylinder, Category 3
- $\Rightarrow 5$ and < 30 l/cylinder, Category 2
- < 5 l/cylinder, Category 1

- **OGV (usually foreign flagged)**
 - Propulsion, category 3
 - Auxiliary, category 2

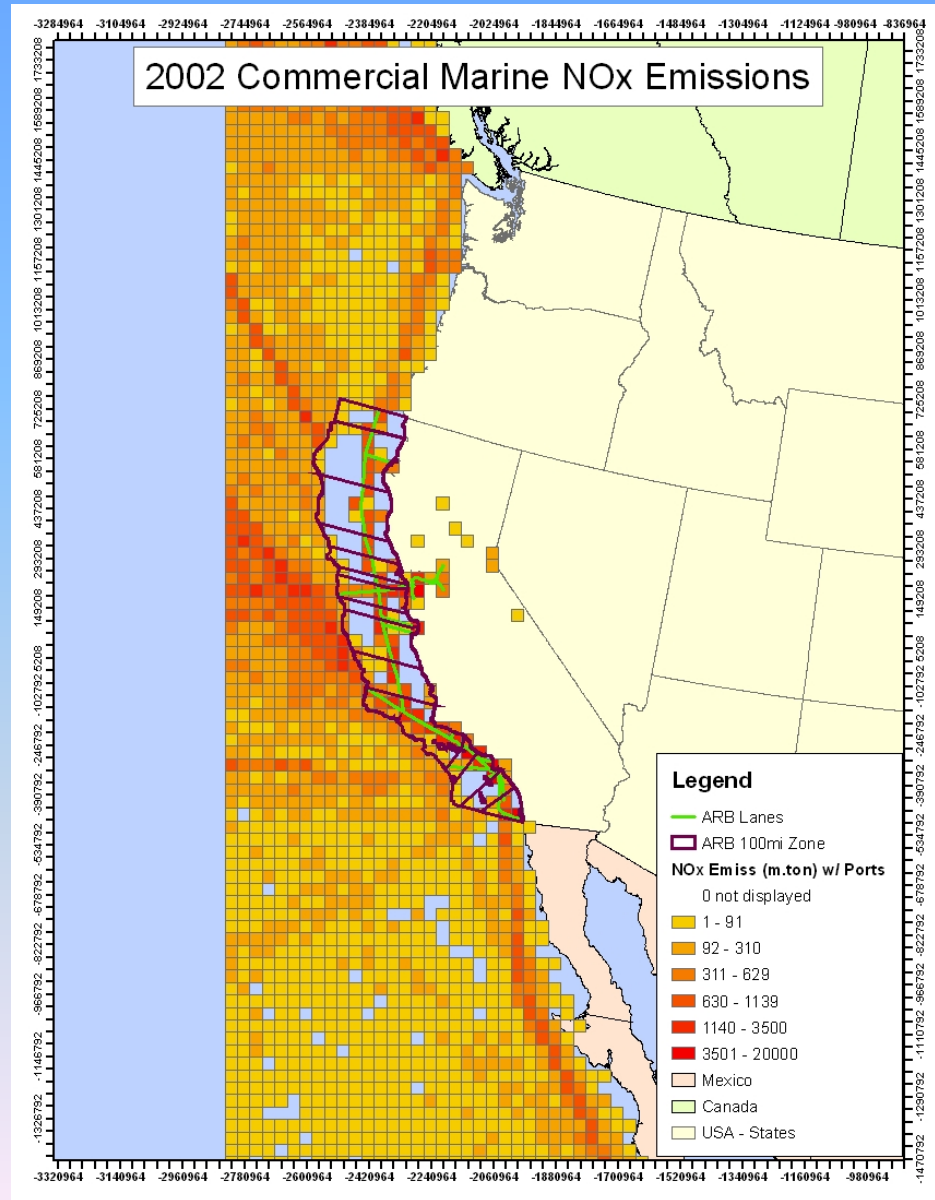
- **Tug and tow**
 - Propulsion, category 1 or 2
 - Auxiliary, category 1

Commercial Marine Emissions Methodology



- Large ocean-going vessel (OGV) in/near port
 - Port calls by vessel
 - Transit links
 - Activity per call
- OGV offshore
 - From work of James Corbett, Univ. of Delaware
 - Uses ship positioning data (a subset of all vessels from a global database)
 - Biased low near shore, so near port grid cells replaced with near port emissions estimates
- California provided OGV and some smaller vessel emissions, including transit emissions within 100 miles of coast

OGV Transit Links Translated to Gridded Emissions



2002 West Coast CMV Emissions

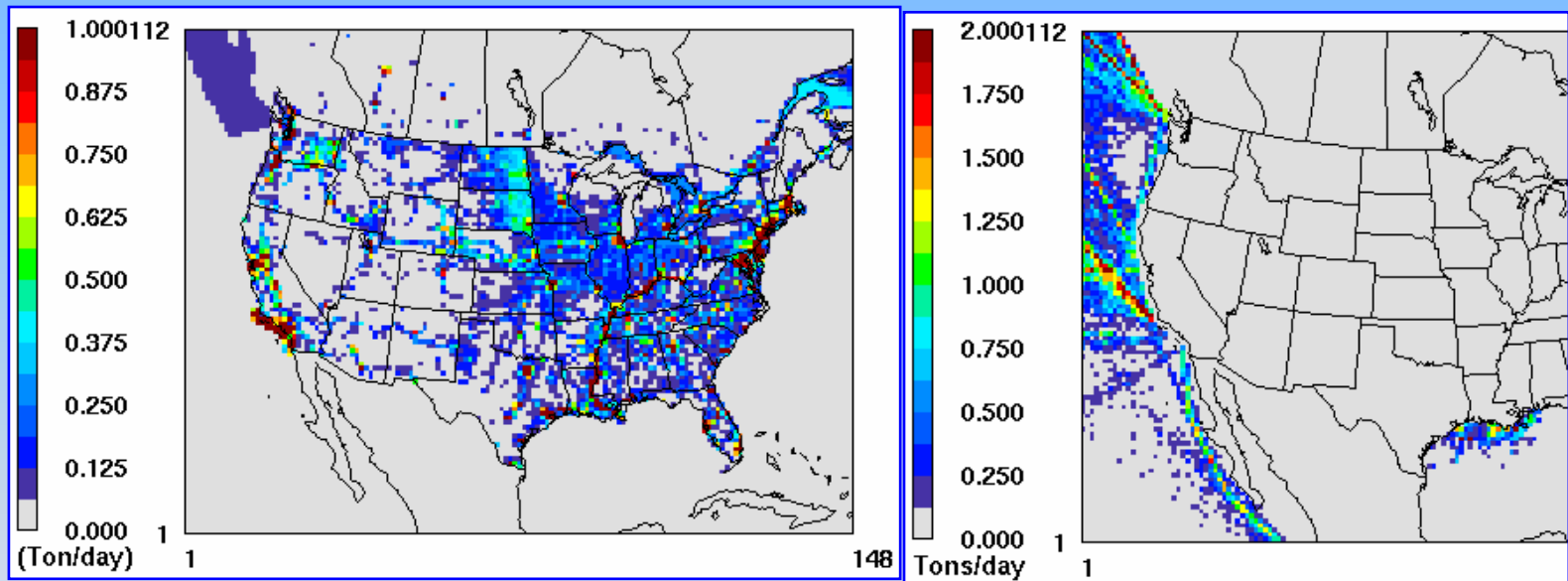
Summary of 2002 West Coast NOx Emissions (tons per year)

State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	243,480	131,930	111,550	NA	NA
Oregon	43,265	41,113	2,152	736	1,415
Washington	58,922	44,692	14,231	3,467	10,764
Total	345,667	217,734	127,933	4,204	12,179

Summary of 2002 West Coast SO2 Emissions (tons per year)

State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	120,240	74,181	46,059	NA	NA
Oregon	23,863	23,119	744	532	212
Washington	32,964	25,130	7,835	2,483	5,352
Total	177,068	122,430	54,637	3,015	5,564

Spatial Distribution of 2002 All RPO Non-Road SO₂ Emissions Compared to Commercial Marine (July Weekday)



2018 West Coast CMV Emissions

Summary of 2018 West Coast NOx Emissions (tons per year)					
State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	478,468	282,351	196,117	NA	NA
Oregon	92,565	87,961	4,604	1,576	3,028
Washington	126,090	95,641	30,449	7,419	23,030
Total	697,123	465,953	231,170	8,995	26,058

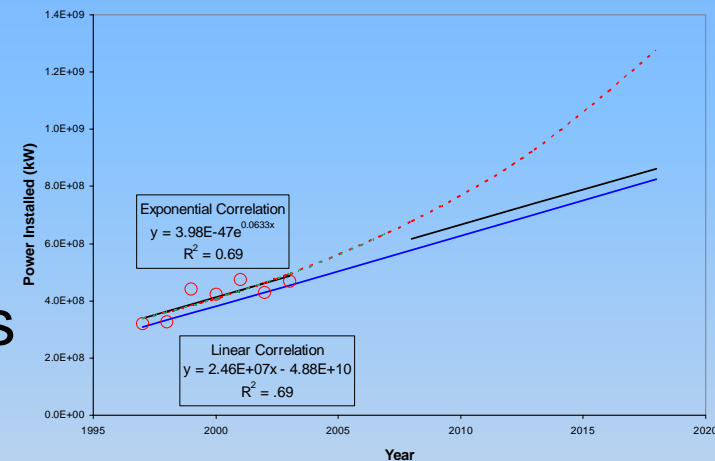
Summary of 2018 West Coast SO2 Emissions (tons per year)					
State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	272,278	178,200	94,079	NA	NA
Oregon	57,304	55,517	1,787	1,277	510
Washington	79,178	60,363	18,815	5,963	12,852
Total	408,760	294,080	114,681	7,240	13,362

West Coast NOx Emissions - % change from 2002 to 2018					
State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	97%	114%	NA	NA	NA
Oregon	114%	114%	114%	114%	114%
Washington	114%	114%	114%	114%	114%
Total	102%	114%	81%	114%	114%

West Coast SO2 Emissions - % change from 2002 to 2018					
State	Commercial Marine				
	Total	Offshore - Zone 1	Coastal/In-Shore - Zones 2,3,4		
			Total	Near-Port - Zone 3	Inshore - Zone 4
California	126%	140%	104%	NA	NA
Oregon	140%	140%	140%	140%	140%
Washington	140%	140%	140%	140%	140%
Total	131%	140%	110%	140%	140%

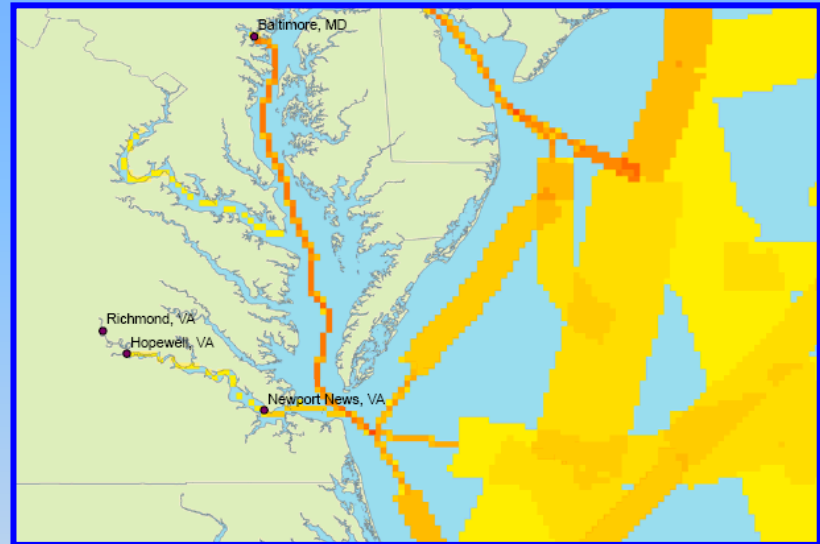
Commercial Marine Projections

- Based on Corbett analysis of historical trends
- Installed power combines propulsion power of individual vessels and number of calls/vessel to coastal ports
- Small number of historical years
- Exponential and linear regression – equal fit
- Used average of exponential and linear fit
- Projection should be considered very uncertain



On-Going Work to Support CMV Emissions Controls

- EPA Sulfur Emission Control Area (SECA) inventories
 - SECA: limit the fuel sulfur within a zone defined by the nation
 - Could extend out to 200 nautical miles from shore
 - Must show impacts to air quality
- CARB is defining more specific routes or links to California ports
- EPA has proposed smaller vessel emissions standards for NO_x and PM, and ultra low sulfur fuel



Key Points on CMV Emissions

- Ocean-going vessels
 - Use very high sulfur fuel (~2.7% fuel)
 - Large source of PM & SO_x emissions
 - NO_x emission rates are high as well
 - Largely outside EPA control because most are foreign flagged
 - Activity forecasts are large and uncertain
- Tug and Tow vessels
 - U.S. Flagged and under EPA new engine and fuels rules

Road Dust Emissions Methodology – Previous Work

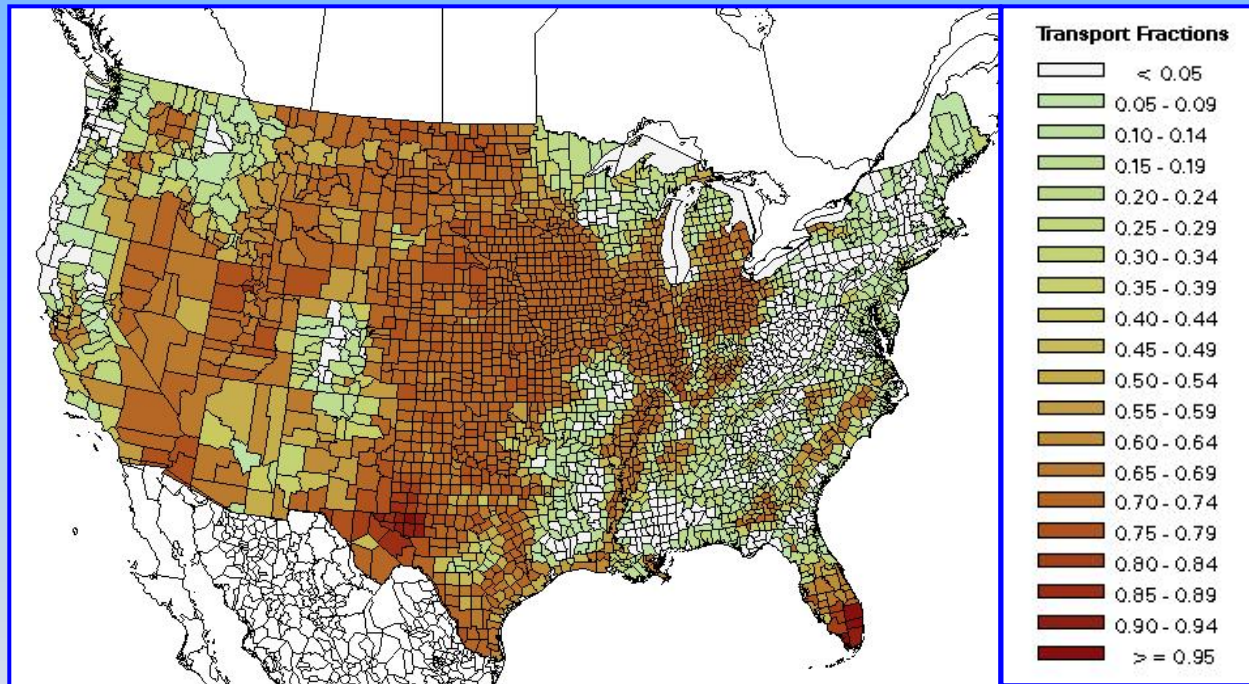
- Revisions were made to unpaved road dust emissions estimates in previous §309 modeling work
- Purposes
 - To develop a better estimate than EPA's divide by 4 approach
 - To resolve large differences in adjacent counties
 - To use consistent methodology across states
- Revisions made
 - Revised average daily traffic volume (ADTV), key parameter in emissions estimate
 - Revised silt loadings
 - Applied transport fractions
- In §309 modeling, removing all road dust had essentially no effect on visibility in Class I areas



Road Dust Emissions – Revisions

- Minimal resources allocated to update VMT estimates for paved and unpaved roads
- Unpaved road VMT estimates were requested from state/local agencies
- Inconsistency in State responses
 - Most States were not able to provide information on unpaved road VMT, or guessed a fraction of paved VMT by county and roadway type
 - Montana used ADTV estimates for unpaved roads, including “off system” roads, to revise unpaved road VMT
- Updated transport fractions were applied in SMOKE to all fugitive dust sources

Dust Transport Fractions

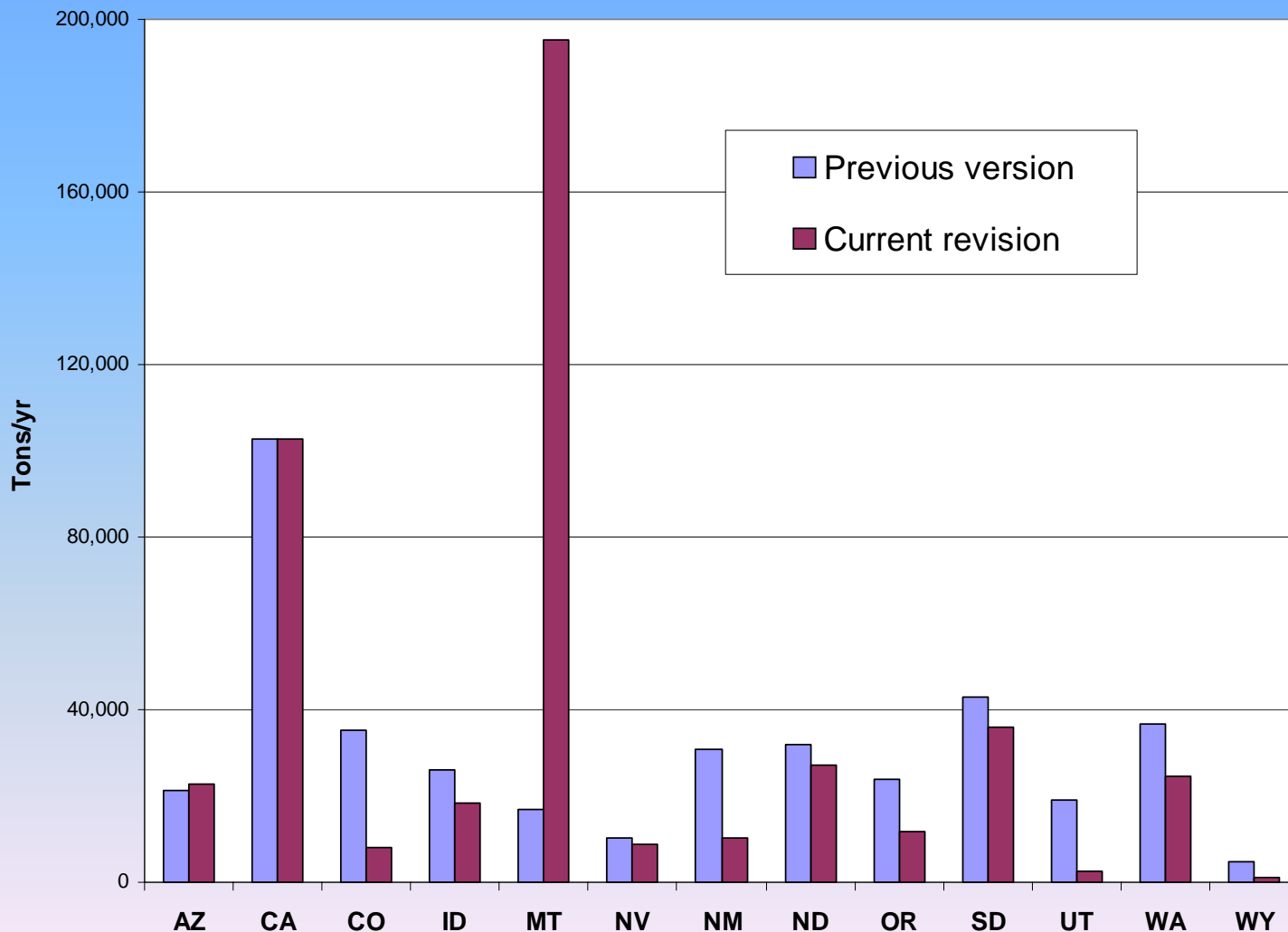


Western States Road Dust Emissions Contribution

Western States road dust as a percent of total dust emissions

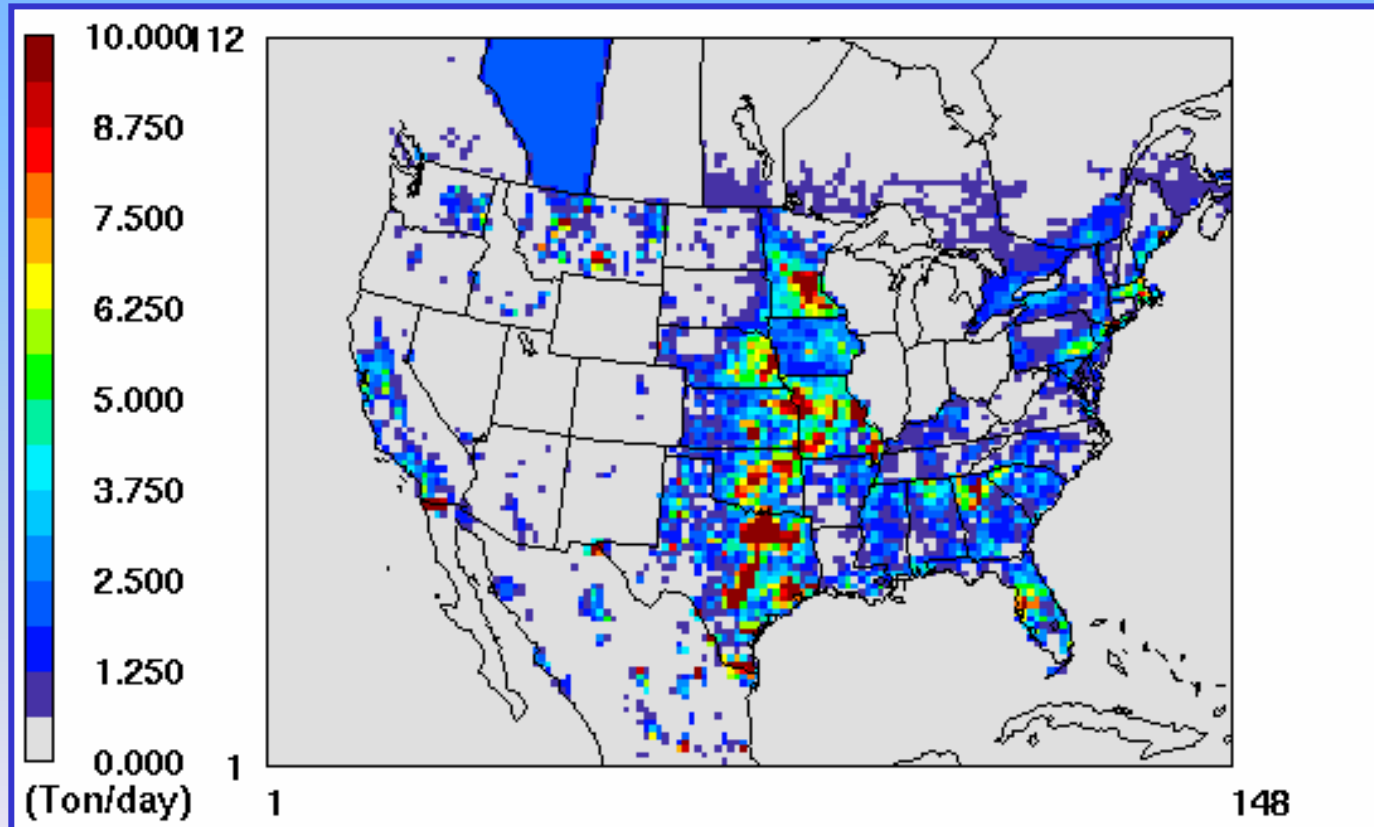
	PM2.5	PMC
2002	4%	16%
2018	1%	18%

Comparison of Previous and Revised Road Dust PMC Emissions

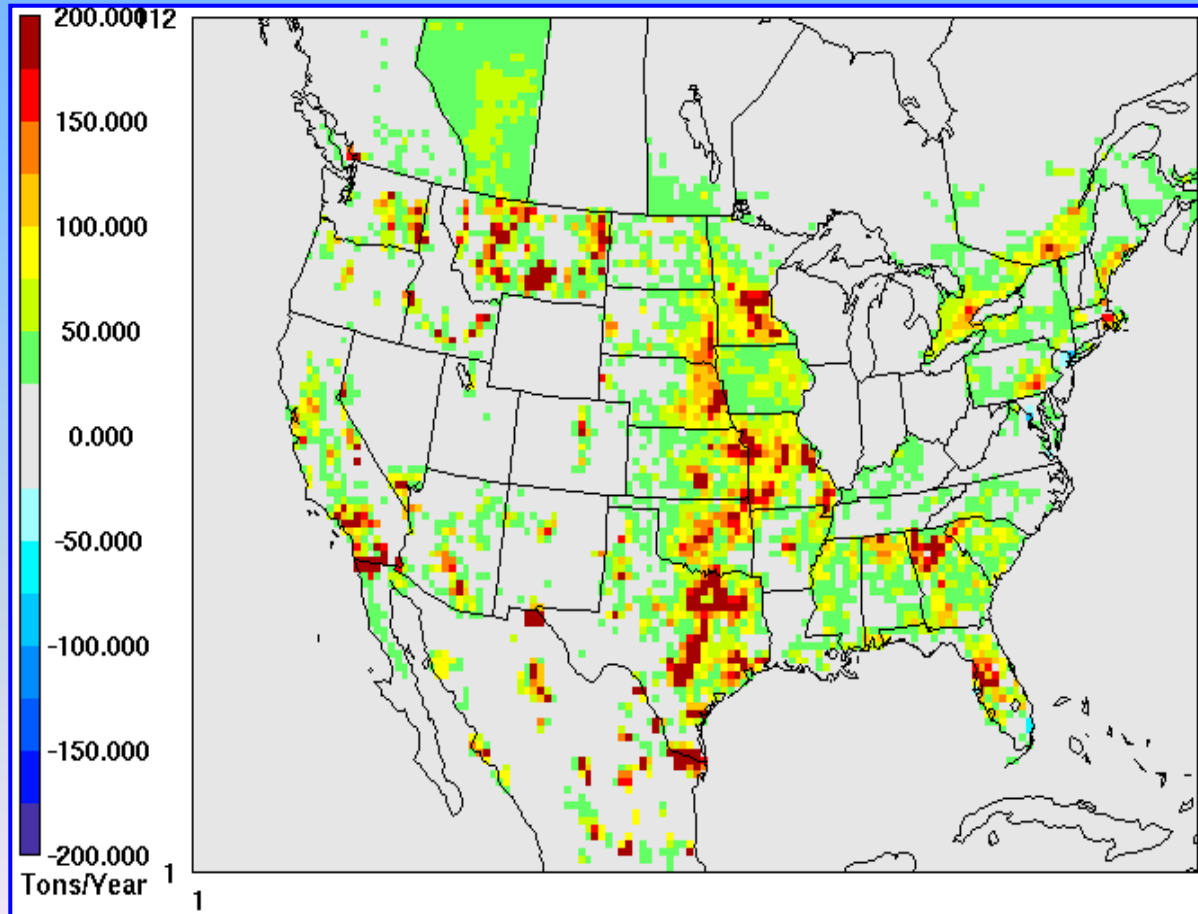


Note – data not available yet for CA revision

Spatial Distribution of 2002 All RPO Road Dust PMC Emissions (July Weekday)



Spatial Distribution of 2018-2002 All RPO Road Dust PMC Emissions (July Weekday)



Key Points for Future Development of Road Dust Inventories

- Road dust emissions are difficult to estimate and can be highly uncertain. Peak emissions are even more difficult to estimate.
- Accurate paved and unpaved road VMT estimates are required, but most state/local agencies do not have estimates of paved vs. unpaved VMT, nor traffic count data on unpaved roads to be able to estimate it.
- Emissions estimates are very dependent on silt content data, which can be very variable even in a small geographical area.
- EPA guidance on estimating paved and unpaved road dust emissions was updated in November 2006. In August 2007 EPA released Policy Guidance on the use of this AP-42 update for SIP development

Mobile Source Emissions Files Available on Project Web Page

- Excel files with detailed emissions by county for each state, 2002 and 2018
- Excel files with plots and data tables of emissions by state for each year
- West Coast States Emissions Summaries
- SMOKE IDA files, 2002 and 2018

<http://wrapair.org/forums/ef/UMSI/index.html>