Toward Improved Basin-Level Oil and Gas Inventories and Reconciliation with Measurements

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WESTERN REGIONAL AIR PARTNERSHIP

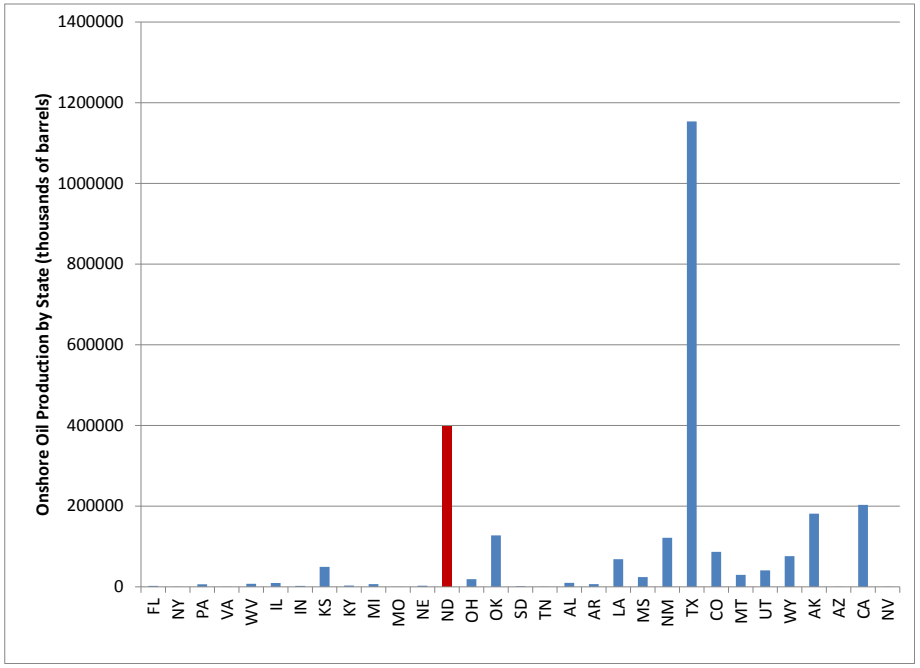
ENVIRON

Overview

- Results from recent WRAP work in the Williston Basin
- Innovations implemented in the Williston inventory
- Reconciliation study with D-J Basin inventory
- Upcoming NETL reconciliation study

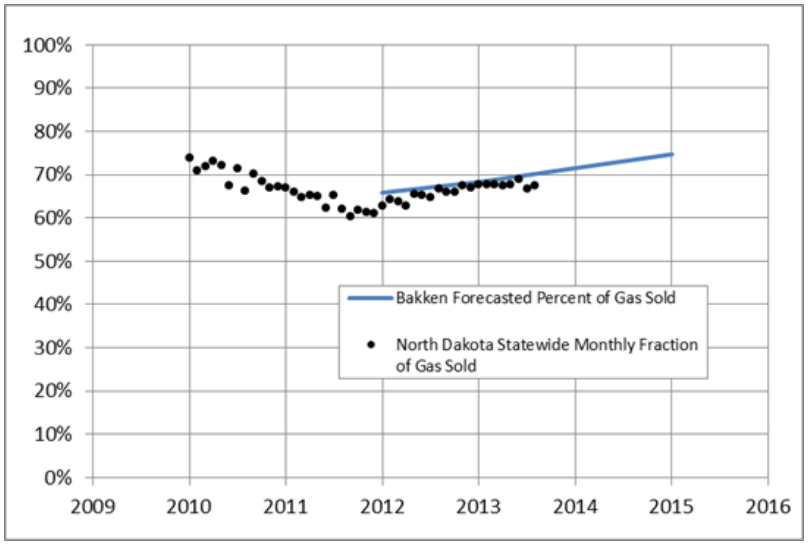
Williston Basin

- Consists of a large area in North Dakota and Montana
- Legacy gas production and recent booming oil production
  - Centered on the Bakken oil shale formation
  - North Dakota now 2nd largest onshore oil production state in the US
  - Significant areas of production on tribal land - Fort Berthold Indian Reservation (FBIR) and limited production on Fort Peck Indian Reservation



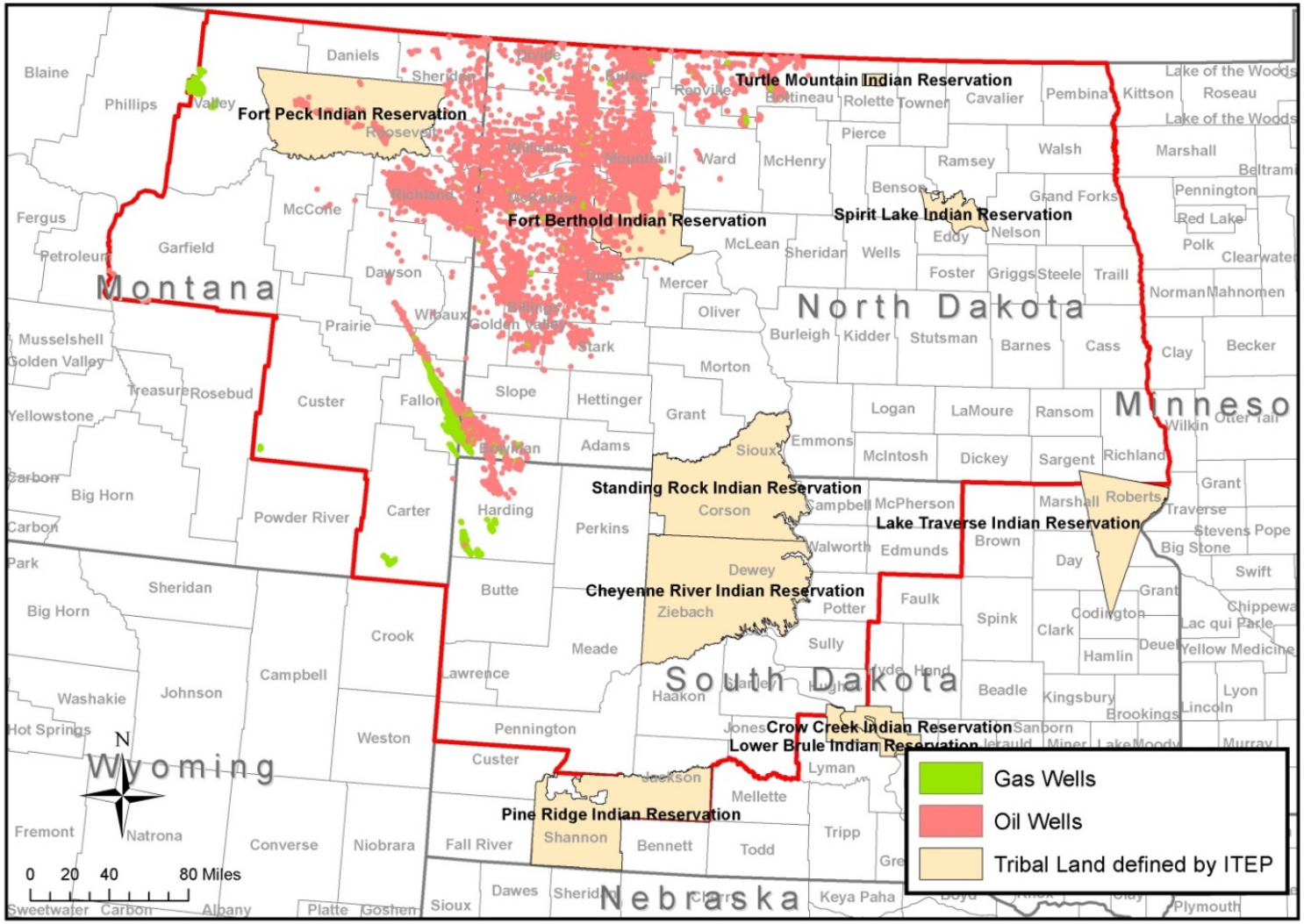
Williston Basin Key Features

- 2011 – roughly 10,000 producing wells and over 175 million bbls of oil production
  - Over 200,000,000 MCF of gas produced of which the vast majority is associated gas
  - Lack of infrastructure to capture and process associated gas



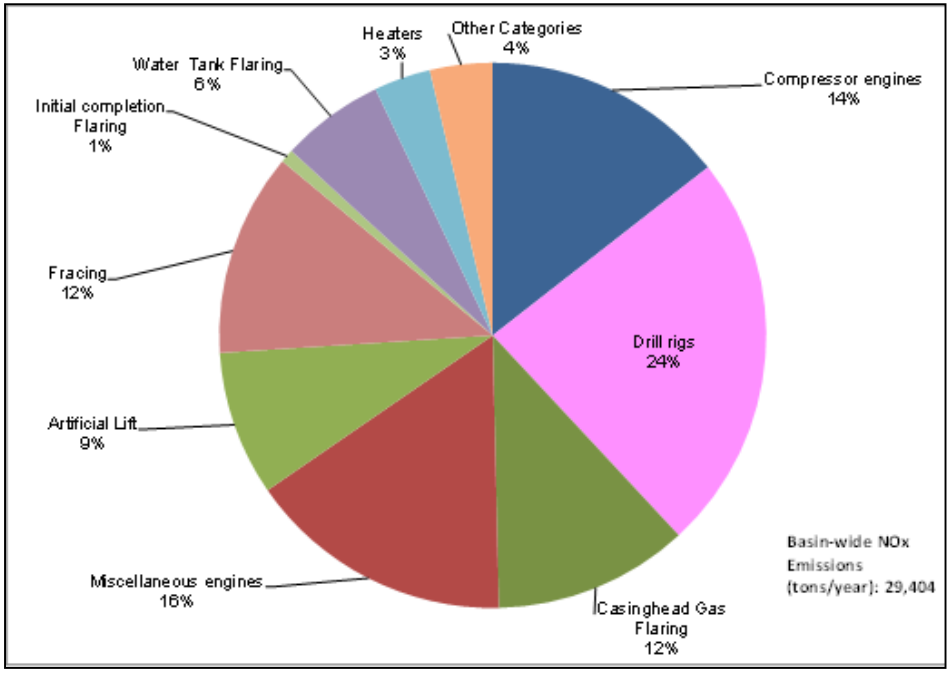
Williston Basin

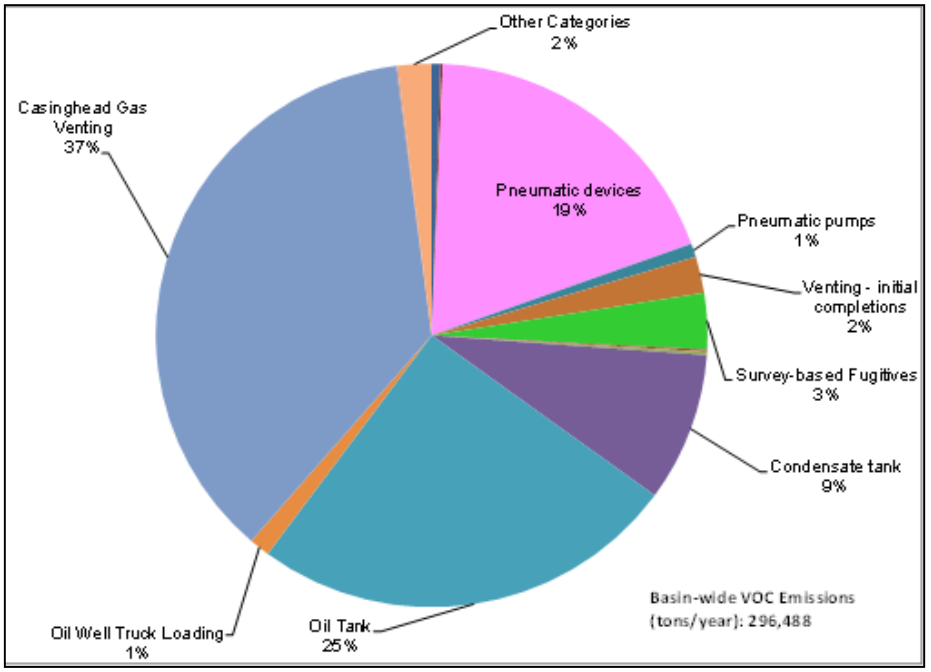
Williston Basin - 2011 Wells



Williston Basin Inventory

Mineral Designation	NOx [tons/yr]	VOC [tons/yr]	CO [tons/yr]	SOx [tons/yr]	PM [tons/yr]
Tribal	3,485	17,306	6,245	432	103
Private/State	22,715	231,430	33,837	5,834	833
BLM	1,738	27,981	3,445	293	72
USFS	1,466	19,771	2,778	337	51
Total	29,404	296,488	46,305	6,895	1,060





Williston Basin – Tribal MNSR

- Subpart OOOO requires reporting of minor O&G sources on tribal land
  - FBIR represented 14%, 8%, and 5% of oil production, gas production, and active well count, respectively, in the Williston Basin in 2011
  - 10 tons per year of carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), or particulate matter (PM), or 5 tons per year of volatile organic compounds (VOCs), or 2 tons per year of hydrogen sulfide (H2S)
  - Midstream sources were separately identified in MNSR registrations and major source inventories provided by EPA Region 8

Williston Basin – Tribal MNSR

- Data mined tribal MNSR registrations for FBIR
  - Over 150 well site registrations randomly sampled
  - Input data for emission calculations
    - Artificial lift engines
    - Casinghead gas
    - Wellhead compressors
    - Fugitives
    - Miscellaneous engines
    - Water tanks
    - Heaters
    - Oil Tanks
    - Truck loading of oil
    - Gas compositions

OIL TANKS				
Parameter		Survey	Tribal MNSR	Units
Representative Input Factors				
% of Tanks	Uncontrolled	10%	0%	-
	Flare	70%	0%	-
	VRU	13%	0%	-
	Enclosed Combustor	6%	99%	-
VOC Emission Factor		5.6	5.4	lb VOC/bbl
		68.2	65.9	SCF/bbl
VOC Mole Fraction		55%	79%	-
Per Surrogate Emissions				
VOC		0.97	0.11	lb/bbl

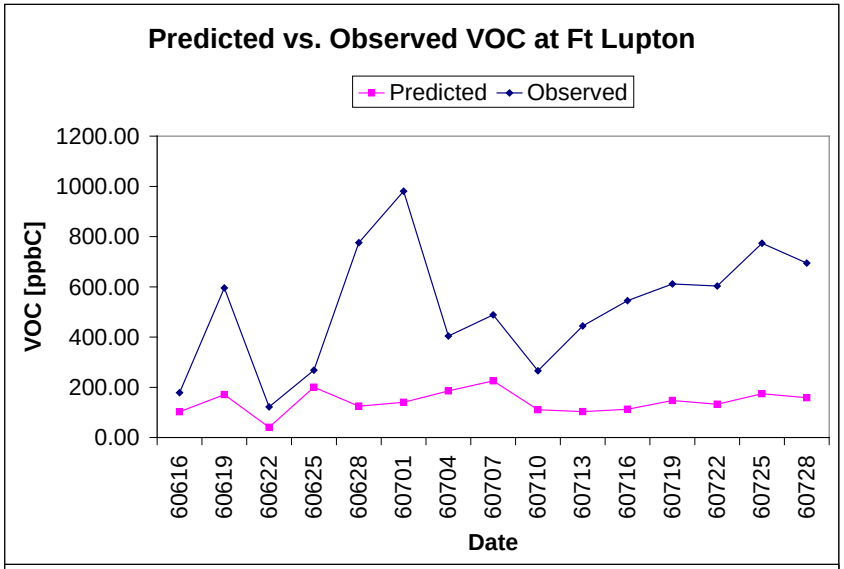
Inventory Reconciliation

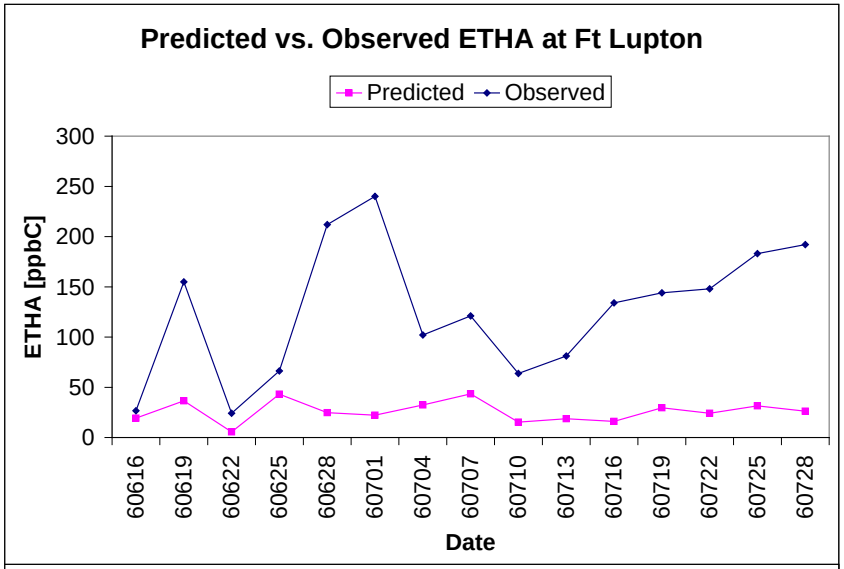
- Reconciliation with top-down measurements of VOC or methane flux
  - Inventories underestimate emissions
  - Reasons unclear
- Examples of reconciliation studies
  - DJ Basin overflight inventories for Weld County and ground tower-based measurements (Petron et al., NOAA)
  - Uinta Basin overflight and ground-based mobile lab measurements (Karion et al., NOAA)
  - Barnett Shale suite of studies by EDF-funded team
  - Denver ozone modeling O&G source apportionment study

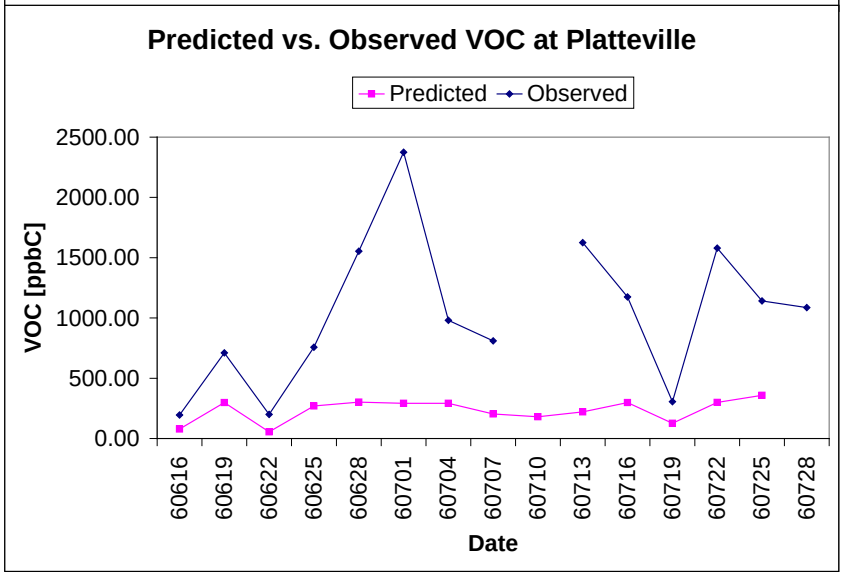
Background

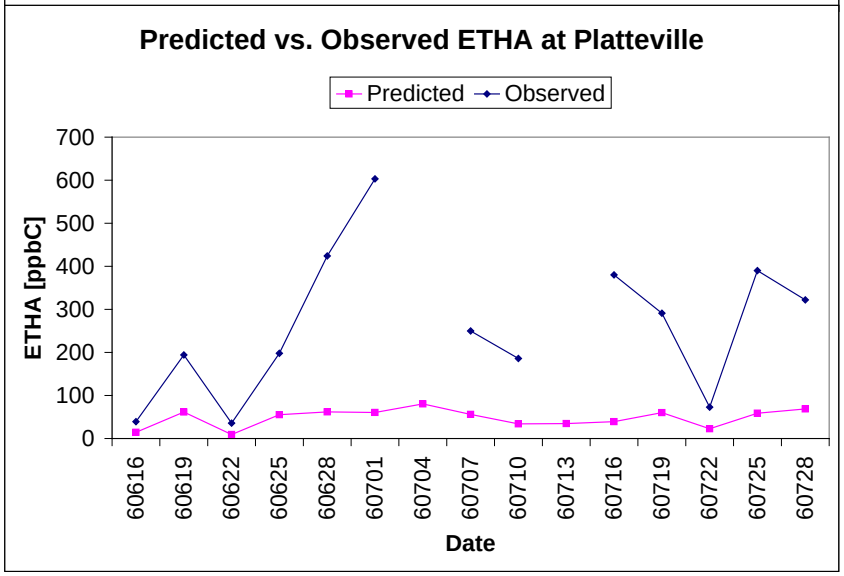
- 2008 Denver ozone State Implementation Plan (SIP) used a June-July 2006 photochemical modeling database to demonstrate attainment of the 1997 8-hour ozone NAAQS (0.08 ppm) by 2010
- During June-July 2006, CDPHE/APCD collected VOC measurements on several days
  - Evaluation of the CAMx photochemical grid model using the VOC measurements found that it underestimated the observed VOC concentrations

VOC and Ethane Underestimated at Weld Co Sites

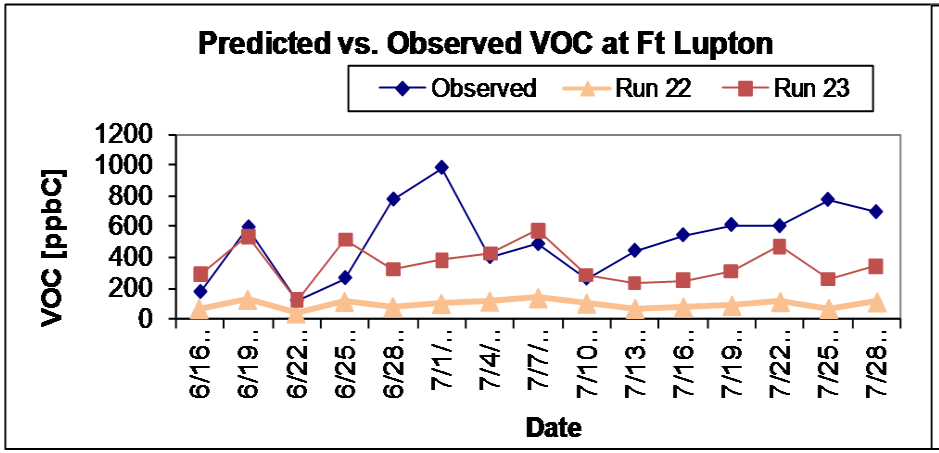


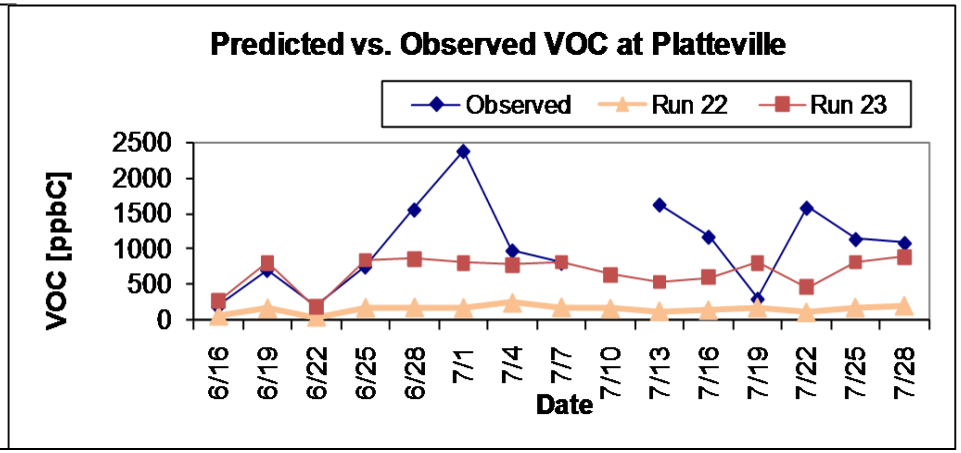




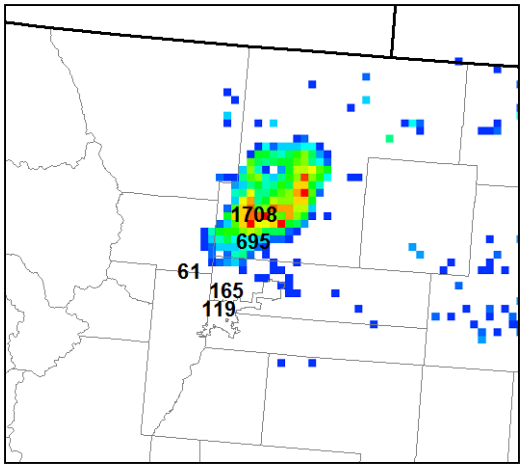


CAMx VOC Sensitivity Test





- No or very small improvements (few ppb at most) in ozone performance on some days/sites
- Significant improvements in VOC at Weld County sites
  - At Platteville, factor of 6 average VOC under-prediction reduced to factor of 1.5

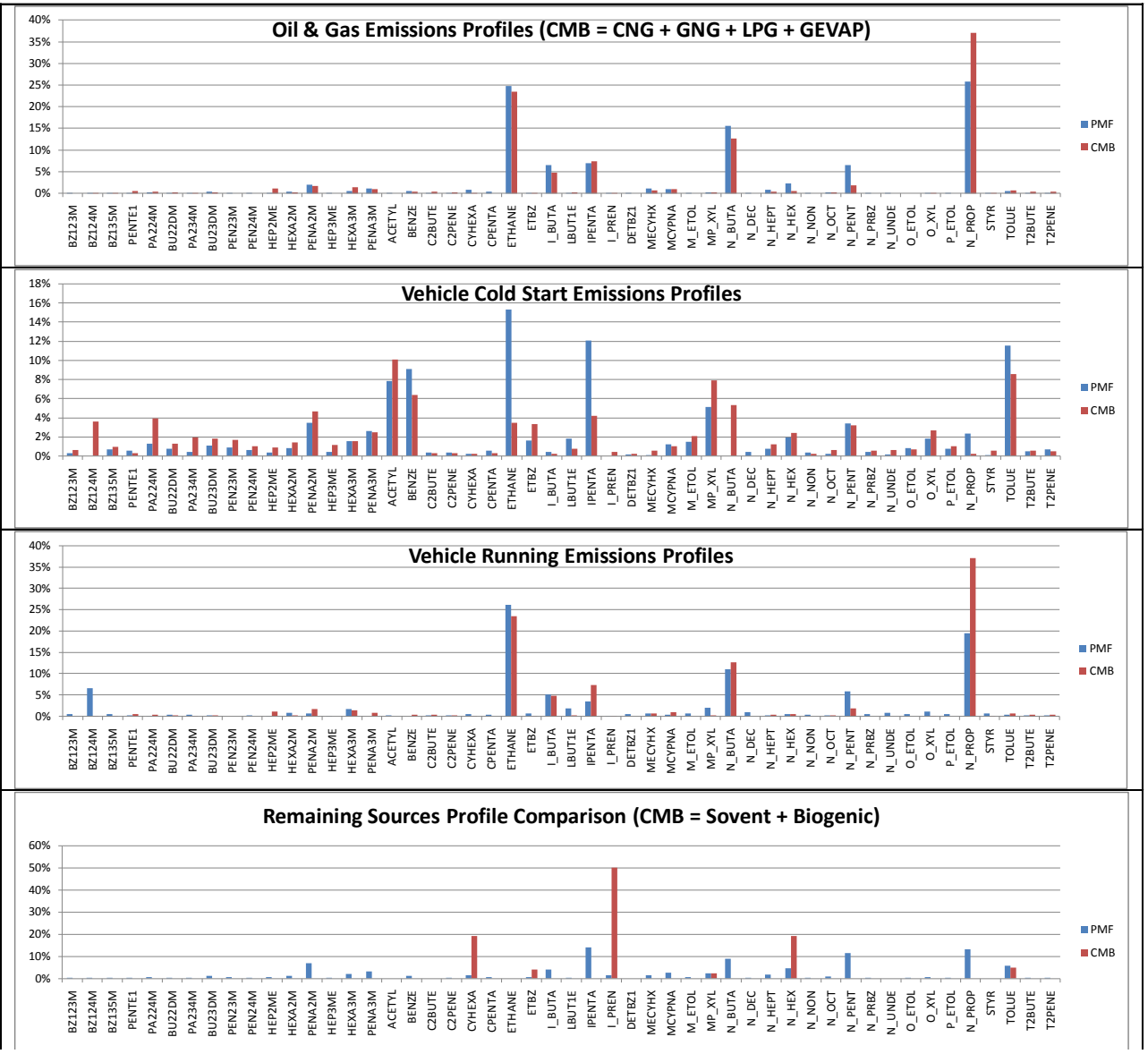


- Days when back trajectories have longer residence time over Weld County O&G sources VOC underestimation bias is the greatest
  - Especially for PAR and ETHA, source signatures for O&G emissions

Preliminary CMB and PMF VOC Source Apportionment

- Input VOC Source Profiles for CMB:
  - Compressed Natural Gas (CNG)
  - Geogenic Natural Gas (GNG)
  - Liquid Petroleum Gas (LPG)
  - Gas Evaporative (Gas Evap)
  - Vehicle Exhaust (Gasoline Combustion)
  - Biogenic
    - Oil and gas sources include combination of CNG, GNG, LPG and Gas Evap
- Preliminary PMF using 4 Factors

CMB and PMF Receptor Modeling

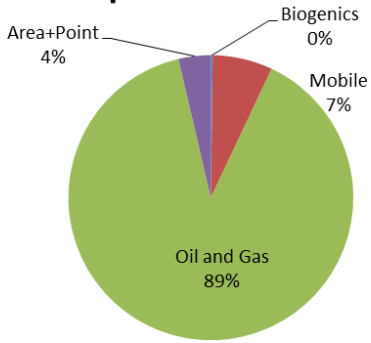


- Very good match between first three PMF factors and Oil and Gas, Vehicle Cold Start and Vehicle Running Exhaust VOC profiles
- Fourth factor compared with Biogenic+Solvent, but not a very good match.

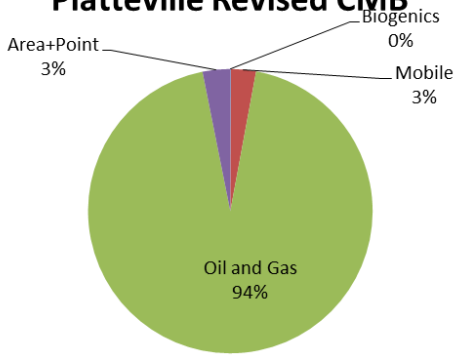
Emissions-Based VOC Source Apportionment Modeling and Comparison to Receptor Modeling

- Use CAMx Ozone Source Apportionment Technology (OSAT) to track VOC emissions for major source categories:
  - Mobile Sources (on-road plus non-road)
  - Biogenic Sources
  - Oil and Gas Sources
  - Area/Point Sources
- Compare CAMx/OSAT VOC source apportionment with Revised CMB and PMF VOC Source Apportionment

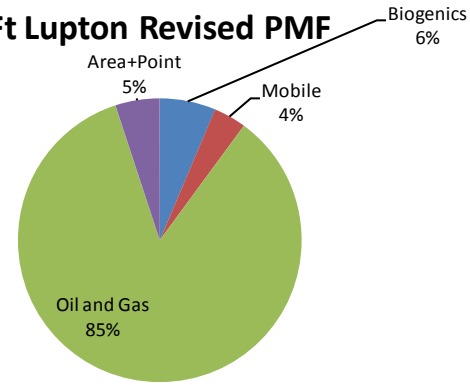
Ft Lupton Revised CMB



Platteville Revised CMB



Ft Lupton Revised PMF



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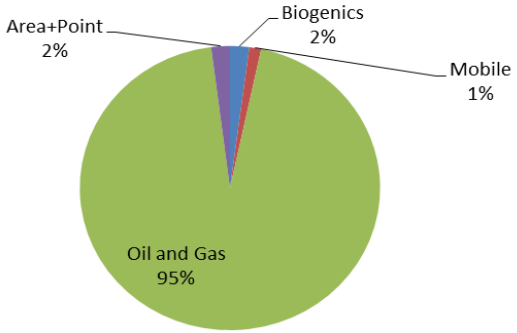
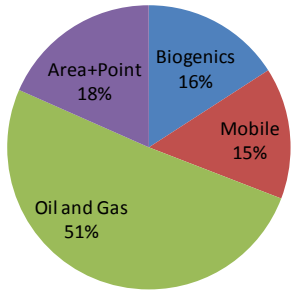
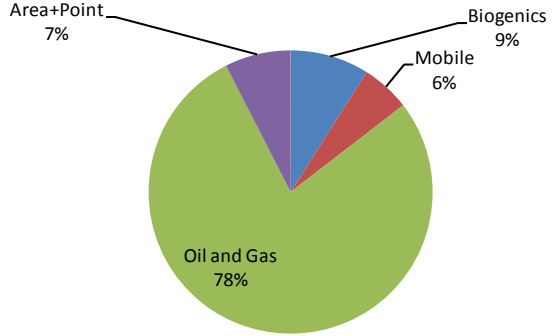


Fort Lupton CAMx OSAT



Plateville CAMx OSAT



Conclusions: VOC Source Apportionment

- Comparison of monitor-based CMB/PMF and emissions-based OSAT VOC source apportionment inconclusive:
  - Is CAMx VOC underestimation bias due to missing VOCs or differences between modeled volume average and surface point measurement
  - VOC source categories in CMB, PMF and OSAT represent different sources
- Results consistent with O&G VOC emissions being understated
  - Work led to FLIR camera purchases and deployment in DJ → condensate tank thief hatch identified as key VOC category

Future Work – NETL Reconciliation Study

- NETL funding a group of researchers (NOAA, NREL, CSU, CSM) to study methane emissions from onshore gas development
  - Includes top-down measurements, bottom-up inventory □ move to reconcile the two
- Improve bottom-up inventories
  - Separate episodic and routine sources through surveys of operator activities
  - Time period of inventory aligned with measurement period
  - Align surveys with Subpart W reporting to access that activity data
  - Use distribution-based EFs & Monte Carlo methods to generate inventory uncertainty estimates

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