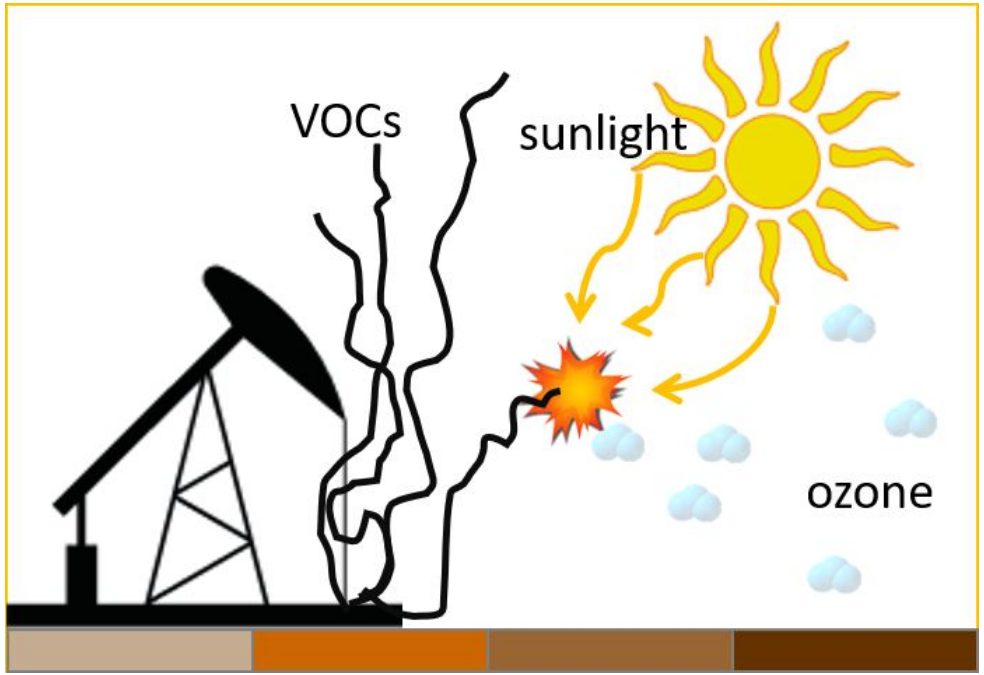
Uinta Basin VOC Composition Study

Final Results Overview & Next Steps

4/2/2020

Goals of Uinta Basin VOC Composition Study



To understand the composition of emissions coming from oil and gas production sites in the Uinta Basin

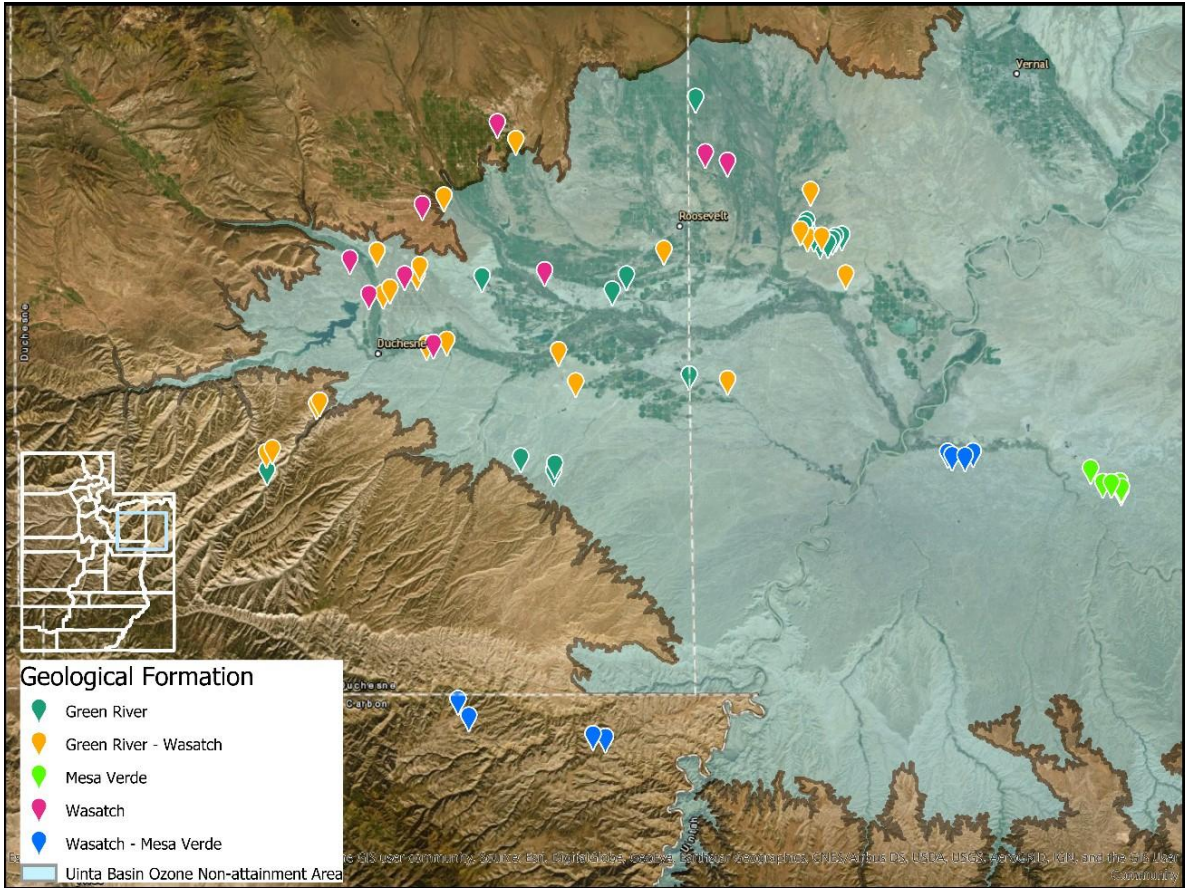
- Improve photochemical modeling of ozone in the Basin
- Improve oil and gas emissions inventory
- Inform permit application best practices

Focus Area

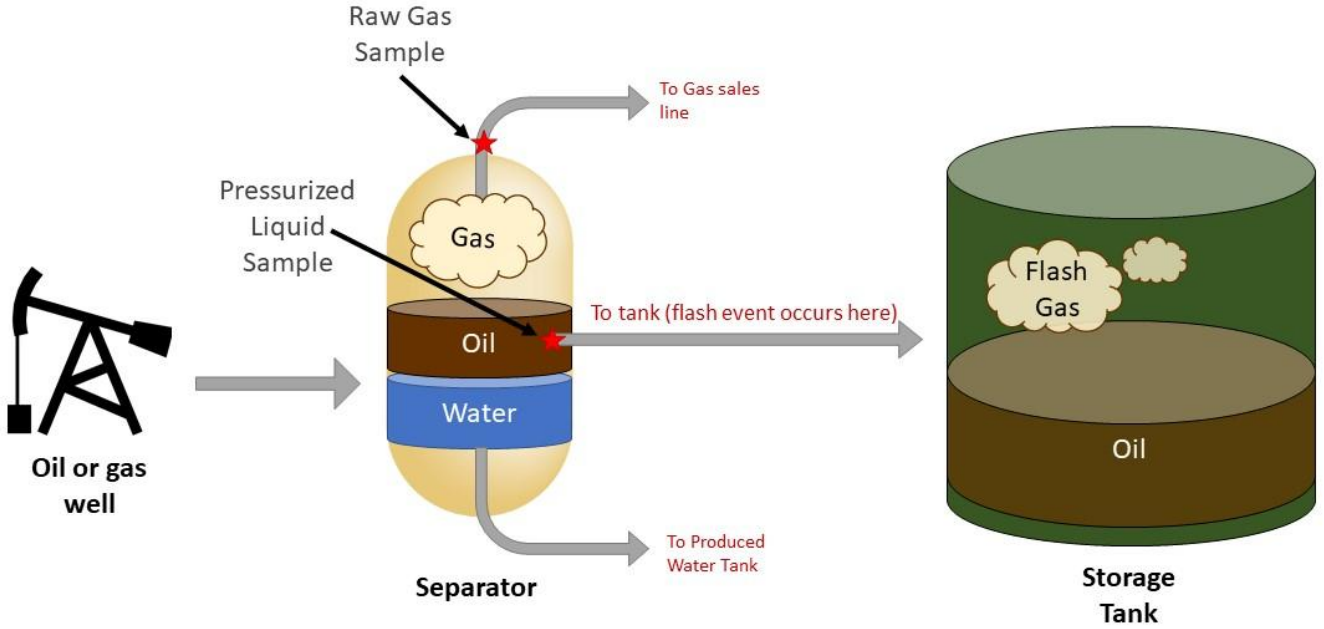
78 wells across the Uinta Basin, including representation on Indian Country

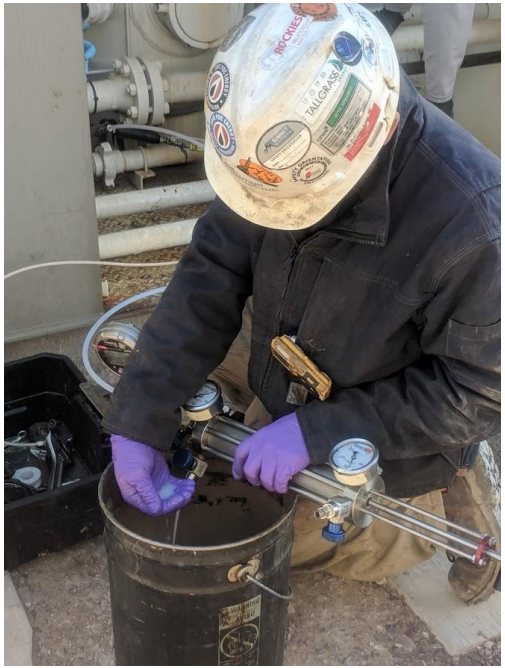
Representing 7 companies (3 gas-producing and 4 oil-producing)

and 5 geological formations



Hydrocarbon Sampling Campaign





67 Wells

Raw Gas

LABORATORY DATA

COMPONENT	MOLE %
HYDROGEN SULFIDE	0.0000
CARBON DIOXIDE	0.9573
NITROGEN	1.1097
METHANE	72.7190
ETHANE	11.0288
PROPANE	6.0052
ISOBUTANE	0.8392
N-BUTANE	2.4056
ISOPENTANE	0.6496
N-PENTANE	1.3413
CYCLOPENTANE	0.0756
N-HEXANE	0.8007
CYCLOHEXANE	0.1610
OTHER HEXANES	0.5652
HEPTANES	0.4989
METHYLCYCLOHEXANE	0.1580
2,2,4 TRIMETHYLPENTANE	0.0001
BENZENE	0.0411
TOLUENE	0.0498
ETHYLBENZENE	0.0019
XYLENES	0.0182
OCTANES	0.2281
NONANES	0.0413
DECANES	0.0929
SUBTOTAL	99.7886
OXYGEN/ARGON	0.2114
TOTAL	100.00

Pressurized Liquid Analysis

LABORATORY DATA

COMPONENT	MOLE %
CARBON DIOXIDE	0.0686
NITROGEN (AIR)	0.0000
METHANE	1.9179
ETHANE	1.3454
PROPANE	1.8681
ISOBUTANE	0.5091
N-BUTANE	1.9796
ISOPENTANE	0.9216
N-PENTANE	2.1725
CYCLOPENTANE	0.1591
N-HEXANE	2.7673
CYCLOHEXANE	0.8671
OTHER HEXANES	1.7900
OTHER HEPTANES	4.0596
METHYLCYCLOHEXANE	1.5502
2,2,4 TRIMETHYLPENTANE	0.0213
BENZENE	0.1484
TOLUENE	0.5178
ETHYLBENZENE	0.0646
XYLENES	0.6353
OTHER OCTANES	5.5827
NONANES	4.9522
DECANES PLUS	66.1016
TOTAL	100.00000

EOS/PSM Flash Gas

LABORATORY DATA

COMPONENT	MOLE %
CARBON DIOXIDE	0.9040
NITROGEN	0.0000
METHANE	26.8007
ETHANE	16.4836
PROPANE	17.6159
ISOBUTANE	3.4594
N-BUTANE	11.3690
ISOPENTANE	3.1354
N-PENTANE	6.2474
CYCLOPENTANE	0.3550
N-HEXANE	3.4564
CYCLOHEXANE	0.8374
HEPTANES	6.5801
METHYLCYCLOHEXANE	0.8033
2,2,4 TRIMETHYLPENTANE	0.0111
BENZENE	0.1668
TOLUENE	0.2267
ETHYLBENZENE	0.0119
XYLENES	0.0907
OCTANES	0.5532
NONANES	0.8172
DECANES PLUS	0.0750
TOTAL	100.00

EOS/PSM FGOR & Stock Tank Oil Characteristics

EOS Flash Liberation of Hydrocarbon Liquid

	Pressure	Temperature
Separator Hydrocarbon Liquid	68 psig	137 °F
Stock Tank	12.3 psia	158 °F
Base Conditions	14.70 psi	60 °F

EOS Flash Liberation Results

	Result	Units
Gas Oil Ratio	31.9	SCF flashed gas/bbl stock tank liquid
Gas Specific Gravity	1.6035	Air = 1.00

EOS Flashed Liquid Properties

	Result	Units
API Gravity at 60 °F	42.2	
Reid Vapor Pressure	3.2	psi

subset of 10 Wells

(Lab measured) Flash Gas + Carbonyls

Compound	Well III-6	Well III-3	Well III-2	Well III-4	Well III-1
Methane	26.12	30.17	31.54	27.50	33.58
Ethane	17.47	19.79	18.49	19.75	20.30
Propane	26.54	24.58	23.72	25.71	23.33
Isobutane	8.14	7.18	7.24	7.69	6.37
n-Butane	11.32	9.98	10.07	10.57	8.62
Isopentane	4.15	3.58	3.86	4.01	3.19
n-Pentane	3.37	2.75	2.84	2.83	2.42
Cyclopentane	0.15	0.15	0.12	0.12	0.13
n-Hexane	1.09	0.76	0.89	0.71	0.72
Cyclohexane	0.49	0.34	0.36	0.32	0.35
Heptanes	0.15	0.12	0.16	0.13	0.20
Methylcyclohexane	0.65	0.37	0.44	0.38	0.44
2,2,4- Trimethylpentane	0.00	0.01	0.01	0.01	0.00
Benzene	0.08	0.05	0.06	0.06	0.06
Toluene	0.12	0.06	0.07	0.08	0.09
Ethylbenzene	0.00	0.00	0.00	0.00	0.00
Xylenes	0.03	0.02	0.03	0.02	0.04
Octanes	0.05	0.04	0.05	0.05	0.07
Nonanes	0.06	0.06	0.06	0.05	0.08
Decanes plus	0.01	0.01	0.01	0.01	0.01
Formaldehyde	3.86E-06	1.58E-05	1.04E-06	1.29E-06	7.80E-06
Acetaldehyde	5.30E-06	4.47E-05	3.67E-03	1.54E-05	3.93E-05
Acetone	0	0	0	0	0
Acrolein	8.82E-05	1.97E-04	2.33E-05	4.51E-04	2.61E-03
Propionaldehyde	0	0	1.90E-05	0	0
Crotonaldehyde	0	0	0	0	4.29E-06
Methacrolein/2-butanone	6.01E-06	6.14E-06	6.10E-06	2.25E-06	2.18E-05
Benzaldehyde	0	0	0	0	0
Valeraldehyde	3.13E-06	0.00E+00	0.00E+00	0.00E+00	8.01E-06
p-Tolualdehyde	0	0	0	0	4.08E-06
Hexaldehyde	0	0	0	0	3.46E-06

Carbonyls

Grouping Composition Data into Profiles

Hypothesis:
Oil and gas composition is similar when samples are collected from the same geological formation

What we learned:
Geological formations reported to UDOGM are not always reliable, and often product from different formations are mixed together in one well

Results:
- 5 raw gas profiles and
- 8 flash gas profiles

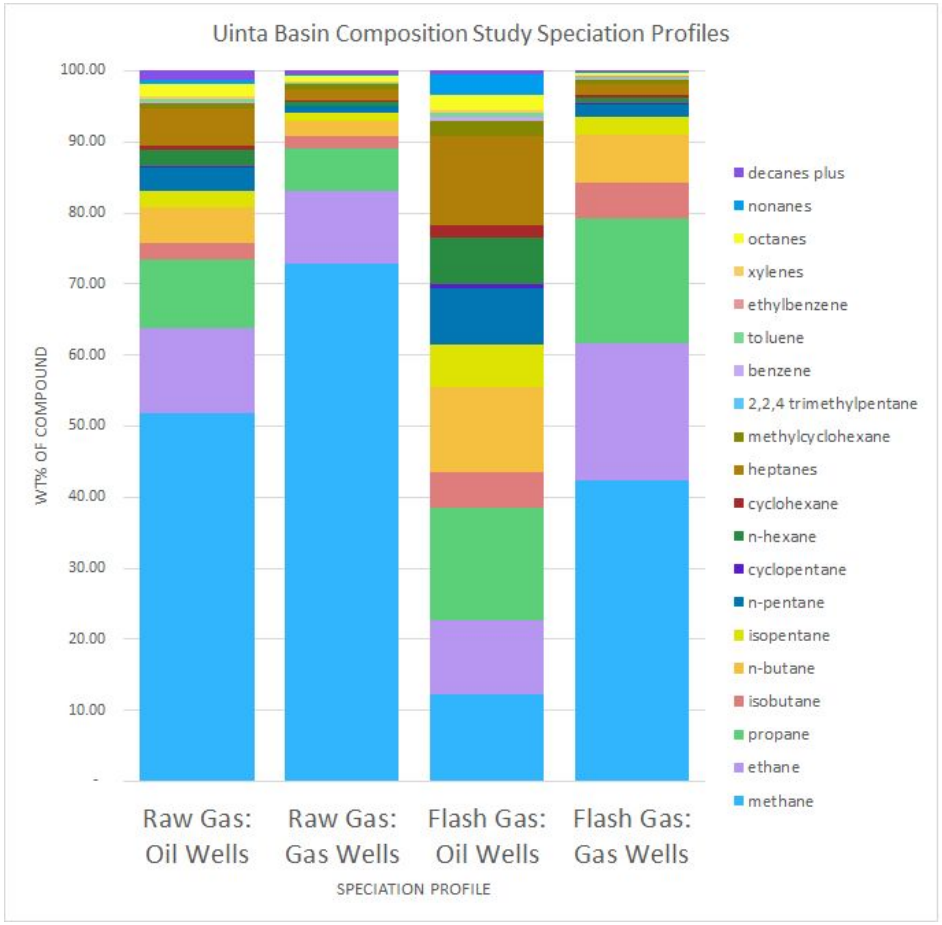
grouped by geological formation and well type (oil or gas)

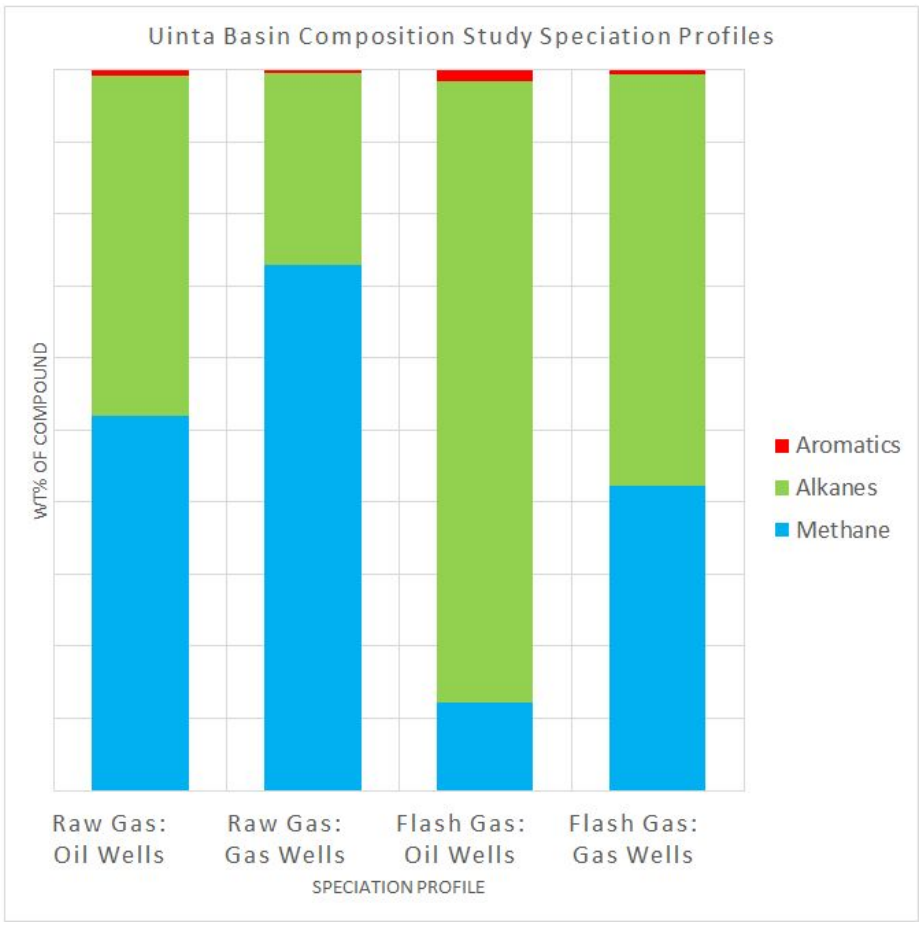
What we made:
- A new application of a robust statistical method to determine the best groups for all 67 wells sampled

What we learned:
Too few samples were collected in each geological formation to determine statistical validity of grouping

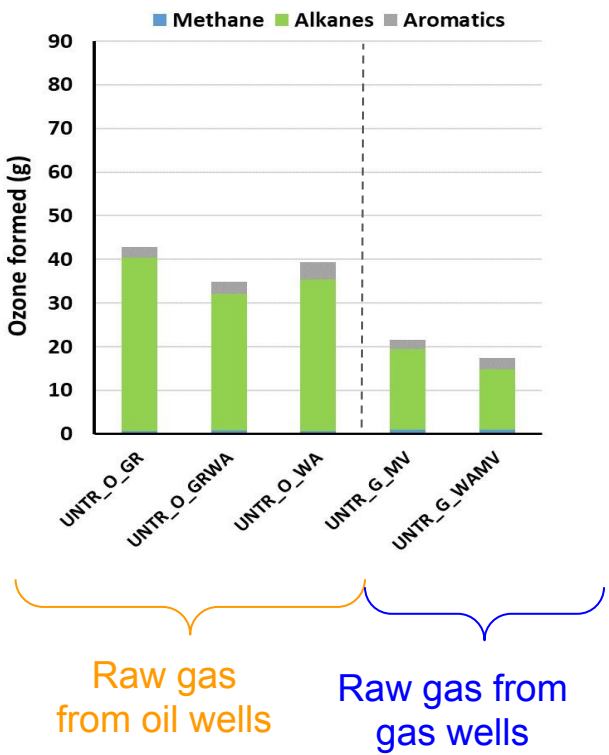
Results:
- 2 raw gas profiles and
- 2 flash gas profiles

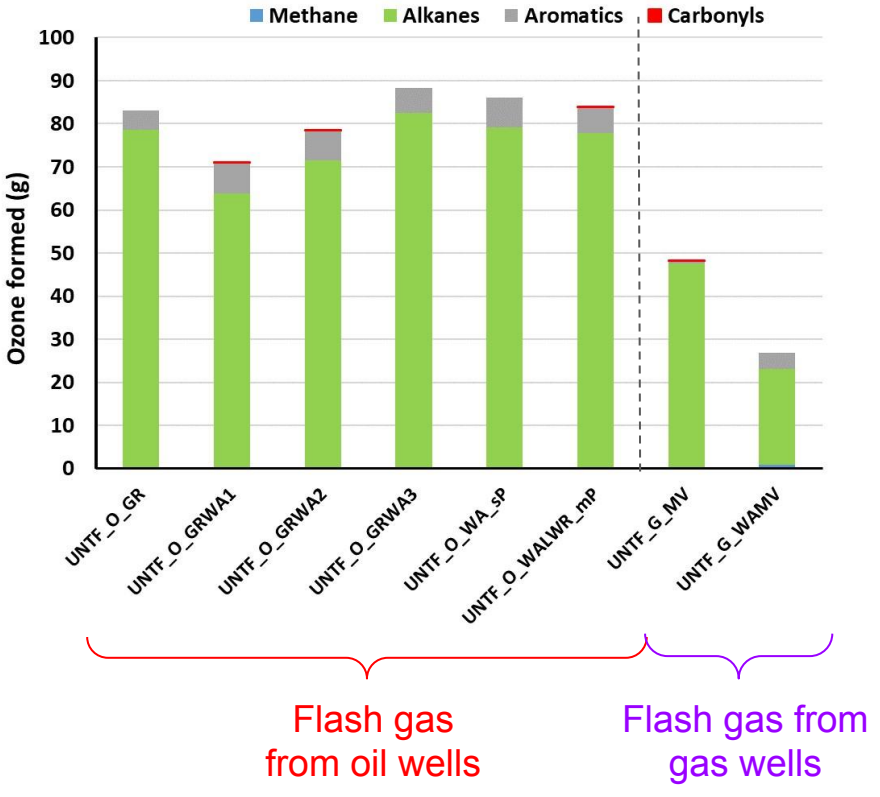
grouped by well type


Uinta Basin Composition Study Speciation Profiles
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
-
WT% OF COMPOUND
decanes plus
nonanes
octanes
xylenes
ethylbenzene
toluene
benzene
2,2,4 trimethylpentane
methylcyclohexane
heptanes
cyclohexane
n-hexane
cyclopentane
n-pentane
isopentane
n-butane
isobutane
propane
ethane
methane
Raw Gas: Oil Wells
Raw Gas: Gas Wells
Flash Gas: Oil Wells
Flash Gas: Gas Wells
SPECIATION PROFILE


Uinta Basin Composition Study Speciation Profiles
WT% OF COMPOUND
Aromatics
Alkanes
Methane
Raw Gas: Oil Wells
Raw Gas: Gas Wells
Flash Gas: Oil Wells
Flash Gas: Gas Wells
SPECIATION PROFILE

Ozone formed, estimated used Maximum Incremental Reactivity (MIR)



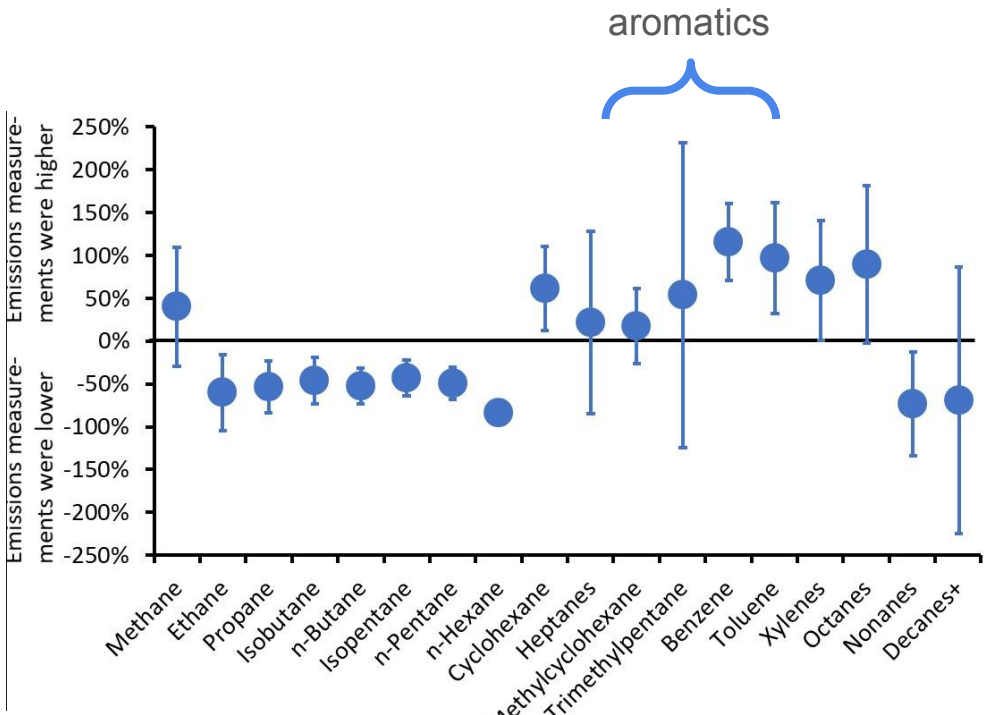


High-flow Sampling

Comparing Flash and Raw gas emissions sampled via separator to

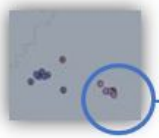
Emissions captured as they leak from active oil and gas equipment

Photo courtesy of USU



High flow measurement shows greater proportion of aromatics than simulated flash gas

Verification Sampling



Resampled 5 wells from original sampling campaign, about 3 months later

Flash Gas Method 1:
- Enter pressurized liquid composition and operating parameters into EOS/PSM

Flash Gas Method 2:
- Heat pressurized liquid sample to separator temp in lab
- Flash sample by depressurizing in bath heated to tank temp
- Measure flashed gas in GC

How do EOS/PSM flash gas compositions compare to lab-measured flash gas compositions?

Pressurized Liquid Composition

LABORATORY DATA

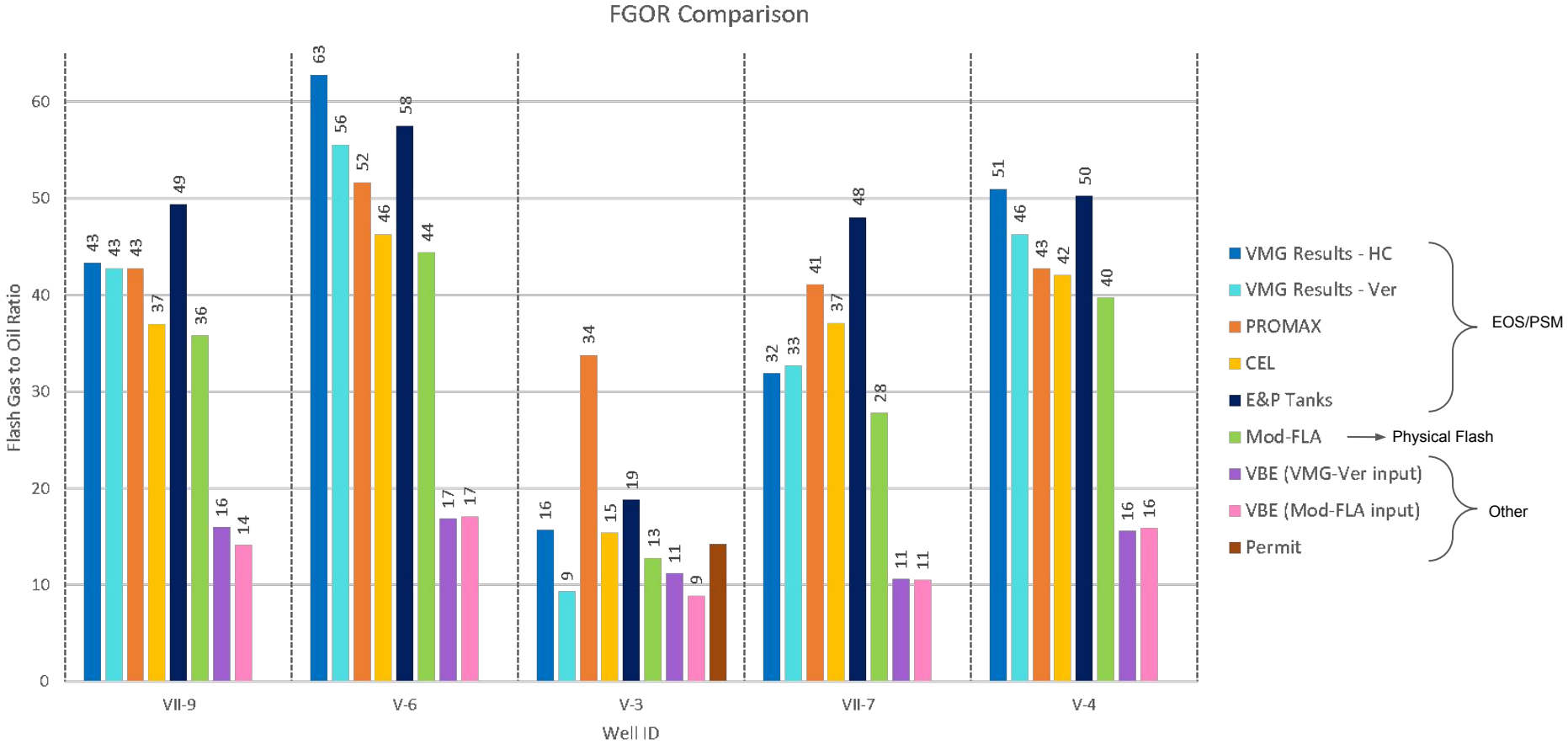
COMPONENT	MOLE %	WT%	LV%
CARBON DIOXIDE	0.0319	0.0055	0.0058
NITROGEN (AIR)	0.0000	0.0000	0.0000
METHANE	1.8991	0.1202	0.3436
ETHANE	1.0073	0.1195	0.2875
PROPANE	1.7231	0.2998	0.5087
ISOBUTANE	0.5712	0.1310	0.1995
N-BUTANE	1.4845	0.3405	0.4995
ISOPENTANE	1.0123	0.2882	0.3951
N-PENTANE	1.2511	0.3562	0.4840
CYCLOPENTANE	0.2310	0.0639	0.0730
N-HEXANE	1.5953	0.5425	0.7002
CYCLOHEXANE	0.8363	0.2777	0.3036
OTHER HEXANES	2.5087	0.8445	1.0366
OTHER HEPTANES	3.1472	1.2343	1.4800
METHYLCYCLOHEXANE	1.5409	0.5970	0.6608
2,2,4 TRIMETHYLPENTANE	0.0233	0.0105	0.0125
BENZENE	0.1400	0.0431	0.0418
TOLUENE	0.4862	0.1766	0.1737
ETHYLBENZENE	0.1146	0.0480	0.0472
XYLENES	0.8242	0.3453	0.3396
OTHER OCTANES	4.7223	2.1133	2.4697
NONANES	4.1840	2.1134	2.4368
DECANES PLUS	70.6656	89.9267	87.5030
TOTAL	100.00000	100.00000	100.00000

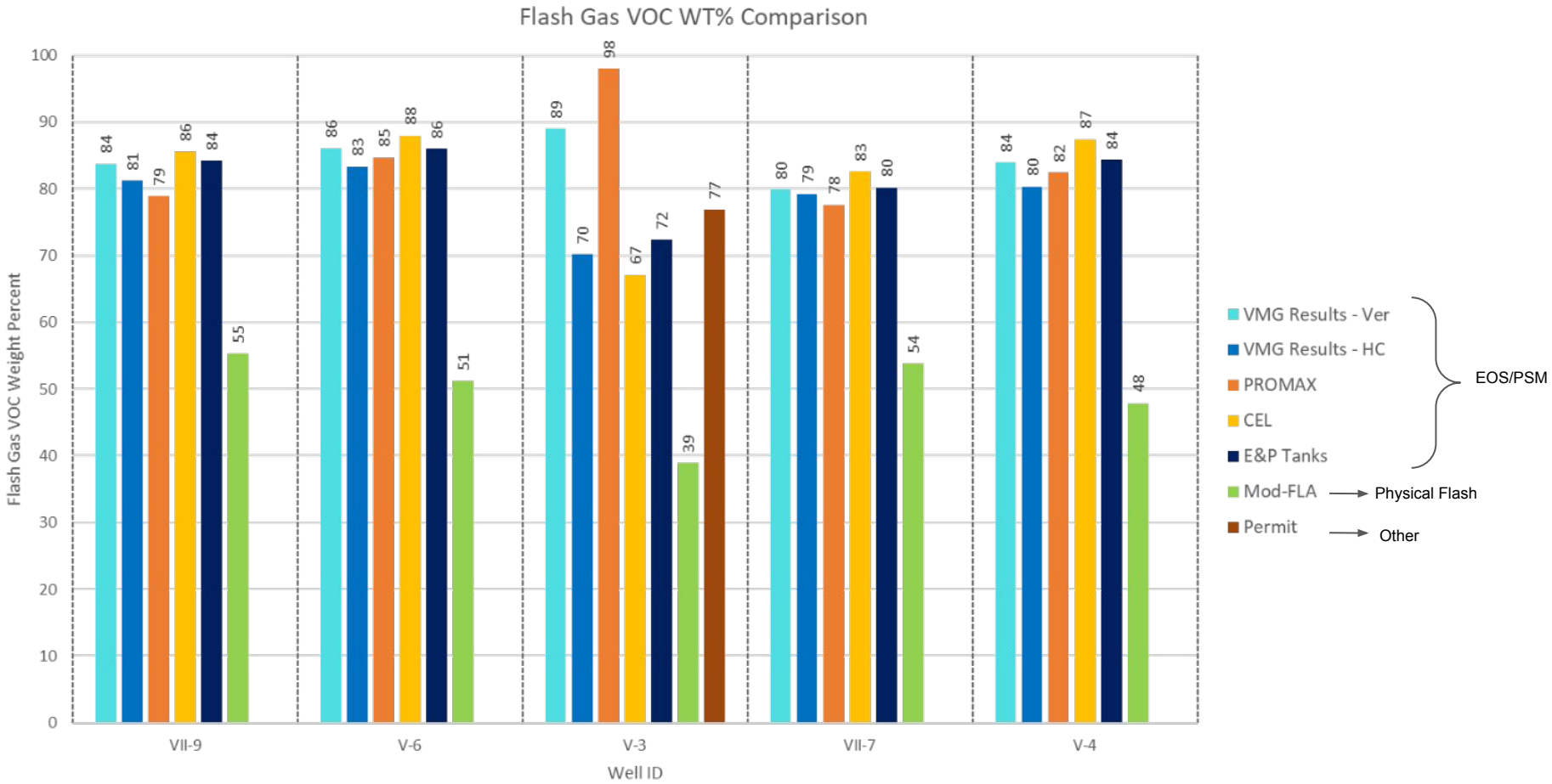
Operating Parameters

- Tank Temperature & Pressure
- Separator Pressure & Temperature
- Production rate

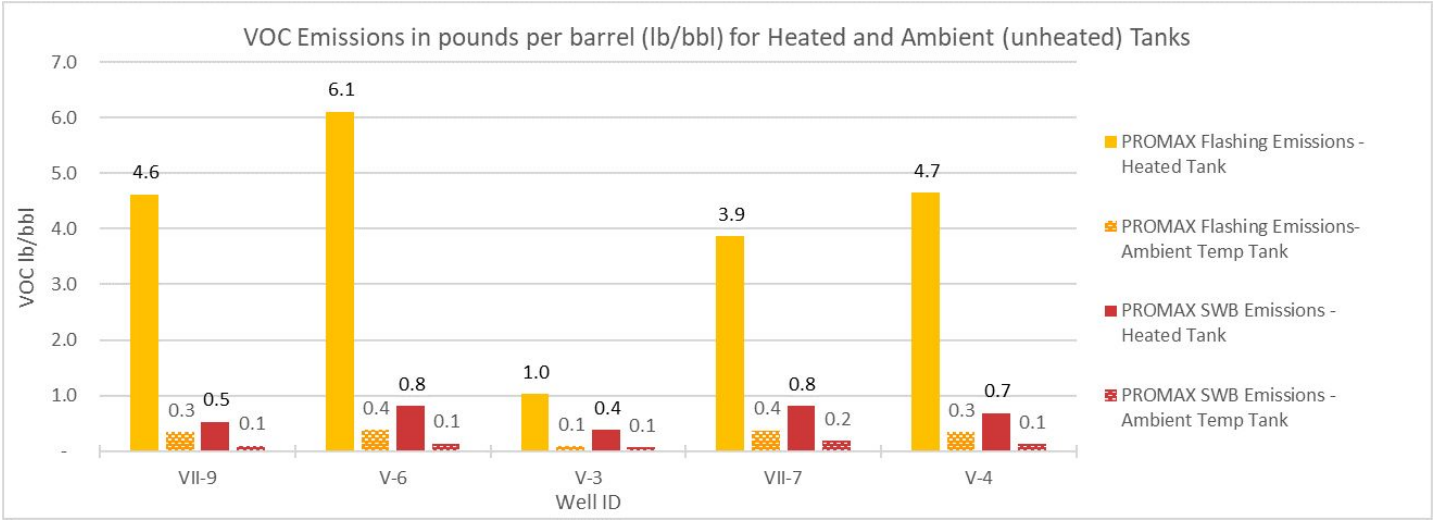
Equation of State/Process Simulation Model (EOS/PSM)

- Flash Gas Composition
- Flash Gas to Oil Ratio
- VOC Emissions (TPY)
- API Gravity of stock tank oil
- Reid Vapor Pressure

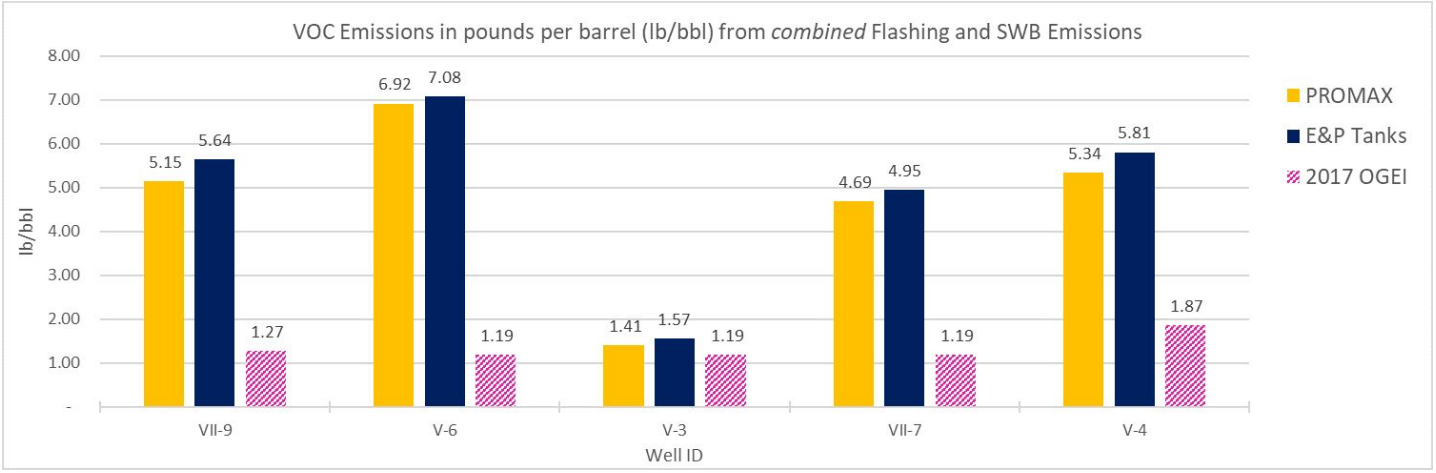

FGOR Comparison
Flash Gas to Oil Ratio
0
10
20
30
40
50
60
43 43 43 37 49 36 16 14
63 56 52 46 58 44 17 17
16 9 34 15 19 13 11 9
32 33 41 37 48 28 11 11
51 46 43 42 50 40 16 16
VII-9
V-6
V-3
VII-7
V-4
Well ID
VMG Results - HC
VMG Results - Ver
PROMAX
CEL
E&P Tanks
EOS/PSM
Mod-FLA
Physical Flash
VBE (VMG-Ver input)
VBE (Mod-FLA input)
Permit
Other


Flash Gas VOC WT% Comparison
Flash Gas VOC Weight Percent
100
90
80
70
60
50
40
30
20
10
0
84
81
79
86
84
55
86
83
85
88
86
51
89
70
98
67
72
39
77
80
79
78
83
80
54
84
80
82
87
84
48
VII-9
V-6
V-3
VII-7
V-4
Well ID
VMG Results - Ver
VMG Results - HC
PROMAX
CEL
E&P Tanks
Mod-FLA
Permit
EOS/PSM
Physical Flash
Other

ProMax Sensitivity Testing



Comparison to 2017 Oil and Gas Emissions Inventory



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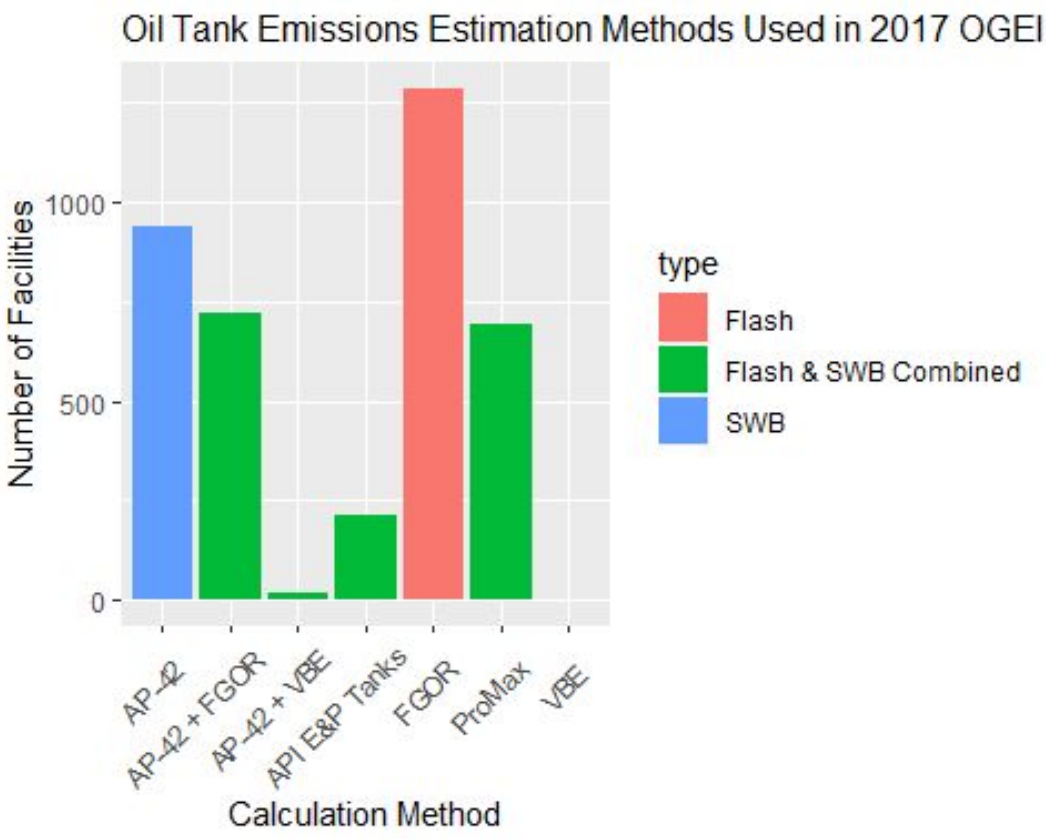
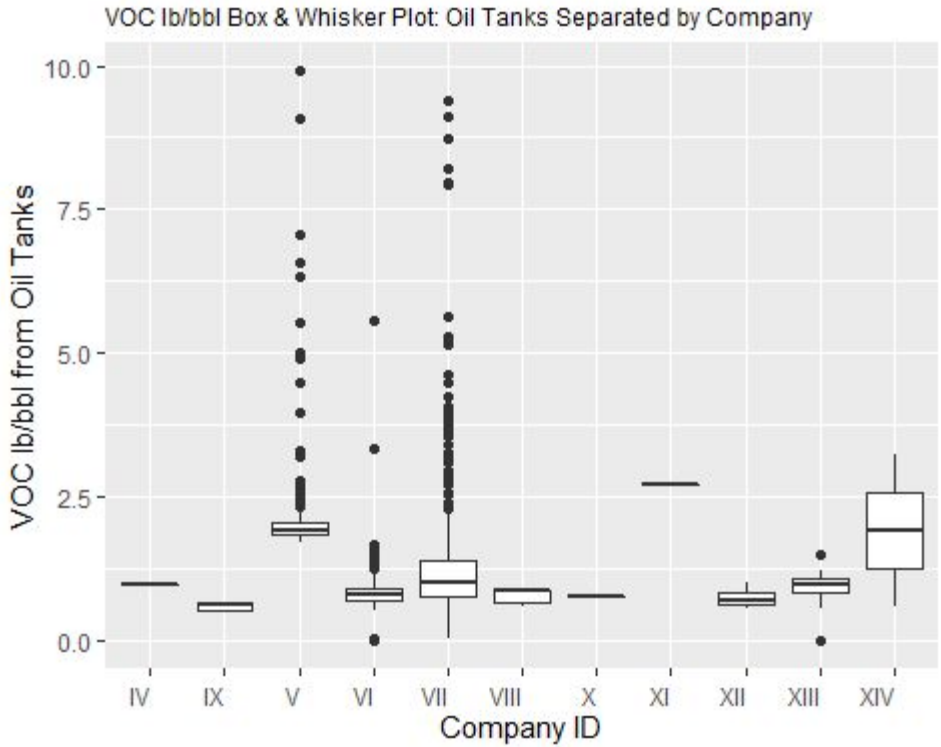
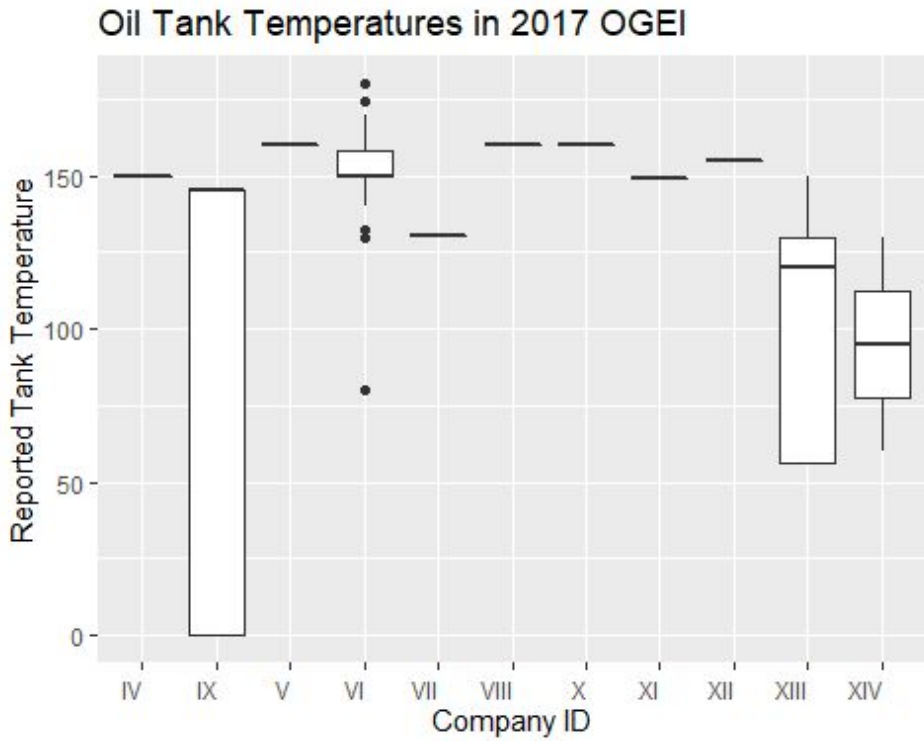


Most operators used EOS/PSM such as
ProMax or E&P Tanks
OR
AP-42 & FGOR
to calculate tank emissions

Comparison to 2017 Oil and Gas Emissions Inventory

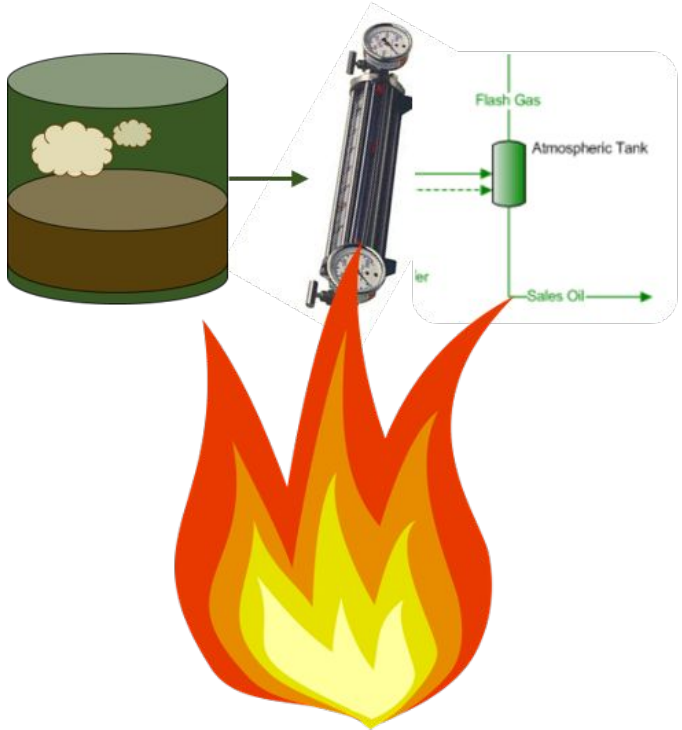
Oil Tanks Only



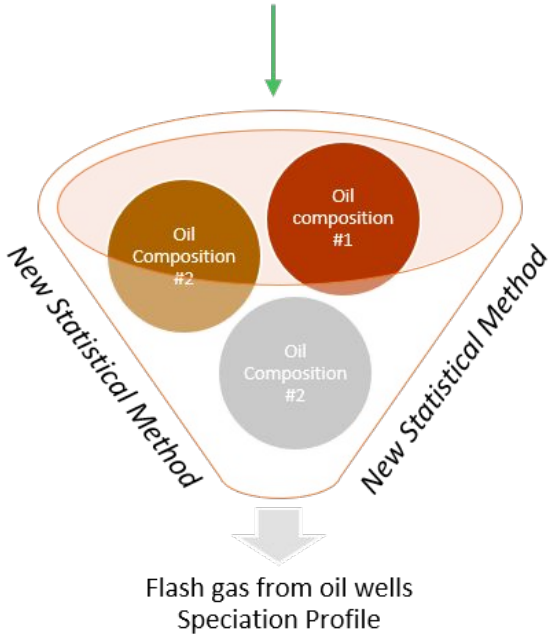


Uinta Basin Composition Study Key Findings

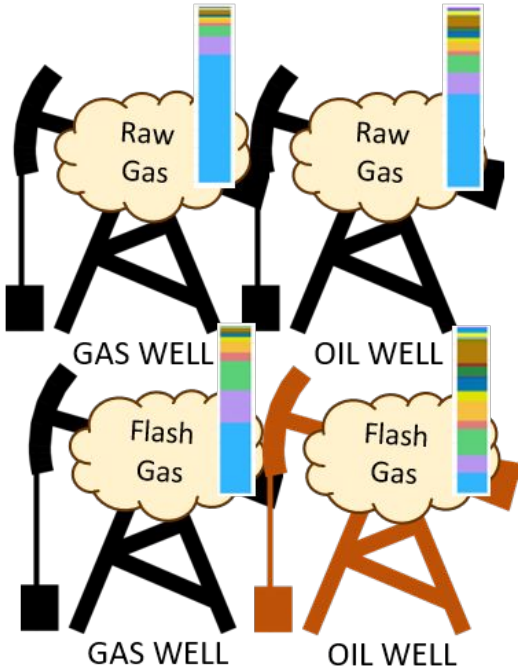
Sample Collection and Analysis



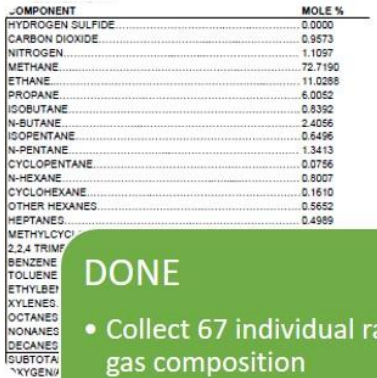
Development of Speciation Profiles



Chemical Composition of Uinta Basin Emissions



Oil and Gas NSR Permitting Applications



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METHYLCYC	
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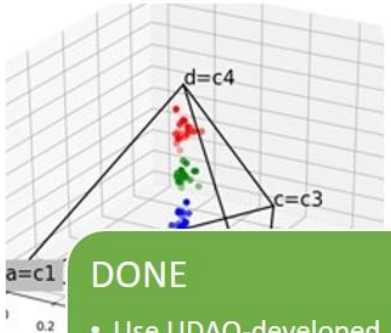
BENZENE	
TOLUENE	
ETHYLBE	
XYLENES	
OCTANES	
NONANES	
DECANES	
SUBTOTA	
OXYGEN	

DONE

- Collect 67 individual raw gas composition
- Collect 67 individual flash gas composition



DONE

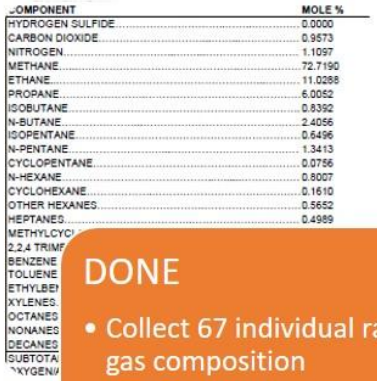
- Use UDAQ-developed method to group individual compositions into representative profiles

m, LLC-	New Source Review	03/10/1983	N10034 533-6 Crude Tanks
m, LLC-	New Source Review	12/19/1986	N10034 Unoca
ration-			
Co - S efinery			
Co - S efinery			

NEXT STEPS

- Build database from existing DAQ permit composition data & expand as new composition data arrive
- Continue to compare/regroup composition data to assess representativeness

Oil and Gas Emissions Inventory Applications



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DONE

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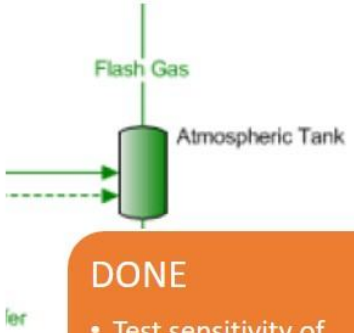
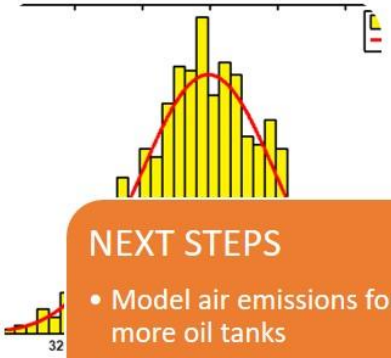


DONE

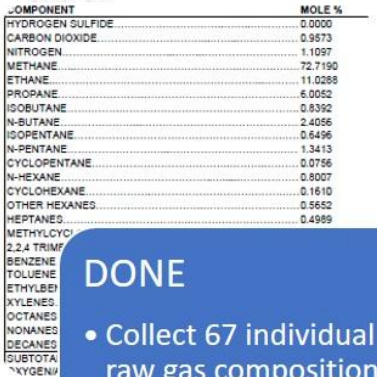
- Test sensitivity of EOS/PSM to various inputs for modeling Uinta Basin heavy crude



NEXT STEPS

- Model air emissions for more oil tanks
- Apply results to emissions inventory using Monte Carlo Simulation
- Update default composition profiles in emissions calculations

Air Quality Modeling Applications



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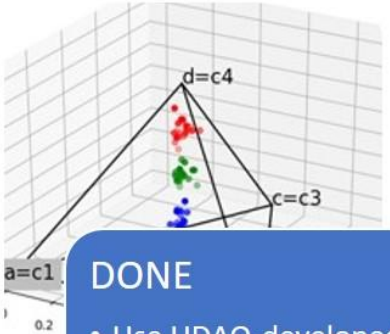
N-BUTANE	2.4056
ISOPENTANE	0.6496
N-PENTANE	1.3413
CYCLOPENTANE	0.0756
N-HEXANE	0.8007
CYCLOHEXANE	0.1610
OTHER HEXANES	0.5652
HEPTANES	0.4989
METHYLCYCL	
2,2,4 TRIMF	
BENZENE	
TOLUENE	
ETHYLBEI	
XYLENES	
OCTANES	
NONANES	
DECANES	
SUBTOTA	
OXYGENA	

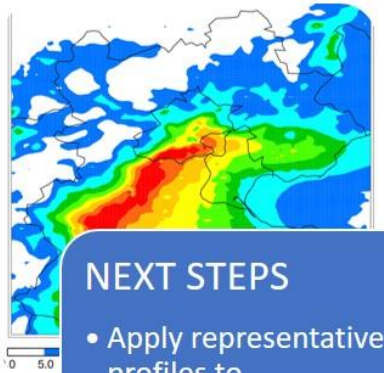
DONE

- Collect 67 individual raw gas composition
- Collect 67 individual flash gas composition



DONE

- Use UDAQ-developed method to group individual compositions into representative profiles



NEXT STEPS

- Apply representative profiles to photochemical model
- Test effectiveness of profiles for ozone production

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