Surface Elevation Contours, Uintah Basin, Utah

[Map showing surface elevation contours with labels for locations such as Vernal, UT, Roosevelt, UT, Red Wash, Horsepool, and Bonanza Power Plant. Distances marked at 1700 m and 1600 m from specific locations.]
Oil (red), Gas (blue) Wells and Measurement Sites, Uintah Basin, Utah
Ozone, NO\textsubscript{x} and Snow Depth: Winter 2009/10

Ouray, Utah Uinta Basin
(Hourly Data)

EPA Standard

Ozone

Snow Depth

NO\textsubscript{x}

Date

Surface Ozone Concentrations at Three Sites, Uinta Basin, Utah 2013 over Three Ozone Events
Uintah Basin, Jan 30, 2013

With special thanks to Detlev Helmig, INSTAAR and his field crew for the Horse Pole soundings
Ozone and Temperature Profiles

Uintah Basin, Feb 5, 2013

Altitude (meters ASL)

Ozone (ppbv)

Temperature (°C)
Mobile Ozonesonde Drive Feb 6, 2013

High Point on Hwy 45 (1720 m) Forms Northern Rim Elevation for Ozone in the Basin

Turn Around Point

Inversion Top (~1600 - 1650 m)
Thank You for Hanging in Until the End!
Thank you for your time and attention.
Ozone in the Uintah Basin, Utah: Winter 2012-13

Ozone profiles, Fantasy Canyon, Feb 6, 2013

Preliminary Ozone Mixing Ratio at Fantasy Canyon, 2/6/2013

Altitude [m]

Ozone Mixing Ratio [ppb]
Surface Ozone Concentrations at Three Sites, Uinta Basin, Utah 2013 over Three Ozone Events
Ozone and Temperature Profiles at Three Sites in the Uintah, Basin

Uintah Basin, Feb 1, 2013

Graph showing ozone (ppbv) and temperature profiles over altitude (meters ASL) for three sites: FC, OU, and HP, on Feb 1, 2013.
Ozone in the Unita Basin of Utah in Winter 2012 and 2013

The difference!
Ozone Time/Height/Concentration Plot, February 6, 2013, Ouray Site
Measuring Effluents from Oil and Gas Field: Uintah Basin
Instrumentation and Displays

- NO
- NO₂
- VOCs
- CH₄
- CO
- CO₂
Example of local sources in the gas field: large fugitive emissions

Compressor Stations in the gas field in the Uintah Basin

- Overall methane levels are very high (often > 2,500 ppb) in the gas field especially under stagnant conditions.
- Fugitive emissions of natural gas are substantial at several locations in the oil & gas fields such as at compressor stations.
- C2+ alkanes are also elevated (> 10s of ppbs) and correlate well with methane.
- Levels are higher at night. They most likely are high under inversion conditions.
Example of local sources in the oil field: Poor engine performance

Natural gas powered artificial lifts & their emission products in the Gilsonite Draw field

- Pumpjack engines in the oil field seem to be very dirty.
- An appreciable percentage of the natural gas used to power these engines can leak to the atmosphere.
Measuring methane leak rates by driving through the plume

Simply drive by to measure plume

A leak is here

and here

and here

and here

and here

and here

and here

and here

and here

and here

Measure here
An example of a plume in the Uintah Basin
(Peak of 25 ppm)
• ~10 miles of road in 15 minutes of driving.
• 23 leaks greater than 10 ppm, 34 leaks greater than 50 ppb (3 per mile traveled)
Methane concentrations in the Uintah Basin

(maximum concentrations >25,000 ppb)

Methane concentrations 3x-12x above background levels over 100’s of square mile from natural gas extraction. Two days.
CH4 Plume Observed 4 Feb 2013  16:27

Car Speed 18.7 m/s
Lateral Wind Speed 0.54 m/s
Flux Estimate >0.34 L/s

Uintah Basin
Feb 7, 2012: Low Wind Conditions
Ozone across the basin on Jan. 31, Feb. 1, 2, and 5
Map of flask samples location in NE Utah

- Roads
- Gas Wells
- Oil Wells
- Bonanza Power Plant
- Compressors
- Processing Plants
- Monitoring Sites
- Surface Air Samples
- Aircraft Air Samples

2012
Airborne flask samples, Uintah Basin, Above and below Inversion 2012 and 2013

![Graph showing the relationship between Benzene (ppb) and Methane (ppm) for the years 2012 and 2013. The graph compares the data from above and below Inversion.]
• Alkanes such as methane and propane are very good markers of natural gas.
• High levels of alkanes were measured in the Uintah Basin, over both the oil (green) and gas (purple) fields
• i-pentane/n-pentane ratio is equal to 1 (typically close to 2 in urban areas).
Vehicle Exhaust Signature in SLC are Not Seen in Uintah Basin

• Benzene and acetylene are used as markers of vehicle emissions.
• The benzene-to-acetylene ratio in Salt Lake City is typical of urban regions.
• Air samples collected in the Uintah Basin show much higher levels of benzene than the Salt Lake City.
Brownish Layer of Bonanza Powerplant Effluents Above Inversion

Cooling Pond Vapor

Ozone is Formed Beneath the Inversion

Bonanza Powerplant Plume, Uintah Basin
Looking WNW
Feb 2, 2013
(aircraft in slight turn)
Power plant layer above inversion apparent in Profiles 1 & 2 in CO, CO₂

Plume between 1800 and 2000 masl has ratio of CO:CO₂ ~6-8 ppb
Layer at higher altitudes (>2000 masl) has more CO, esp. in western side of basin.
Horse Pool, Jan 25 - Feb 18, 2013

Ozone Vertical Distribution
Uintah Tethered Balloons

Bonanza Power Plant Plume
Conclusions

• **Snow** is key to the meteorology and chemistry of winter ozone formation. No snow, no ozone.
• **Bonanza** power plant is not a contributor to NOx or ozone in winter Uintah ozone formation.
• The ozone precursors are coming from oil and gas extraction and transport processes.
• Transport of ozone and ozone precursors from outside the Basin is inconsequential.
• The depth of the enhanced ozone layer is shallow, varying from the equivalent of one to three 150 feet drill rig heights.
Thank you for your time and attention.
Uintah Basin, Feb 2013

CH4 Plume Observed 31 Jan 2013  13:00

- Car Speed: 13.0 m/s
- Lateral Wind Speed: 1.5 m/s
- Flux Estimate (Left): >3.2 L/s
- Flux Estimate (Right): >1.3 L/s
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS: Uintah Basin</td>
<td></td>
</tr>
<tr>
<td>Car Speed</td>
<td>18.8 m/s</td>
</tr>
<tr>
<td>Lateral Wind Speed</td>
<td>1.4 m/s</td>
</tr>
<tr>
<td>Flux Estimate</td>
<td>&gt;2.9 L/s</td>
</tr>
</tbody>
</table>
Example of Emission Factor Derivation

Natural gas leaks in oil field & combustion products

<table>
<thead>
<tr>
<th>Molar ratio</th>
<th>Pad #</th>
<th>CO/CO₂</th>
<th>CH₄/(CO₂+CO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>85%</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>23%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>52%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>19%</td>
<td>61%</td>
<td></td>
</tr>
</tbody>
</table>
Ozone Events and the Bonanza Powerplant Plumes Aloft
Ingredients For Fast, High Concentration Wintertime Ozone Production

• Precursor atmospheric effluents from natural gas and oil field operations.

• Effluents constrained within a geographical basin that hampers mixing.

• Snow deep enough to cover shorter vegetation.

• Temperatures cold enough to maintain the snow cover.

• Low winds.

• Clear skies.

• Maintenance of a strong temperature inversion.
1 = 10 a.m.  2 = 11 a.m.  3 = noon  4 = 1 p.m.
5 = 2-3 p.m.  6 = 4-5 p.m.  7 = 6-8 p.m.
Feb 7, 2012: Low Wind Conditions

Steve Conley (Scientific Aviation/ UC Davis)
Physiography: Uinta Basin, Utah

Scale: 100 km

Uinta Basin

Elevation:
- ~3.3 km
- ~2.1 km
- ~2.0 km
- ~1.8 km
- ~1.4 km
- ~2.2 km
- ~2.4 km
Gas wells

Oil wells

Feb 4, 2012

Methane (CH₄)

CH₄ (ppb)

2223.33 to 2250
2196.67 to 2223.33
2170 to 2196.67
2143.33 to 2170
2116.67 to 2143.33
2090 to 2116.67
2063.33 to 2090
2036.67 to 2063.33
2010 to 2036.67
1983.33 to 2010
1956.67 to 1983.33
1930 to 1956.67
1903.33 to 1930
1876.67 to 1903.33
1850 to 1876.67
Tethered Balloon Profiles at Ouray

- Jan. 26: End of an event (Jan. 29).
- Jan. 27: Beginning of the next event (Jan. 31).
- Jan. 29: End of an event (Jan. 29).
- Feb 1: Ozone (ppbv)
- Feb 3: Ozone (ppbv)
- Feb 5: Ozone (ppbv)
- Feb 6: Ozone (ppbv)
Ozone across the basin on Jan. 31, Feb. 1, 2, and 5

- January 31
- February 1
- February 2
- February 5
Correlation of $O_3$ with $CH_4$ and with CO, Feb. 1, 2, 4, 5, 6

Aircraft continuous measurements both below and above the inversion.
Airborne flask samples, Uintah Basin, Above and below Inversion 2012 and 2013
Airborne flask samples, Uintah Basin, Above and below Inversion 2012 and 2013
Airborne flask samples, Uintah Basin, Above and below Inversion 2012 and 2013