

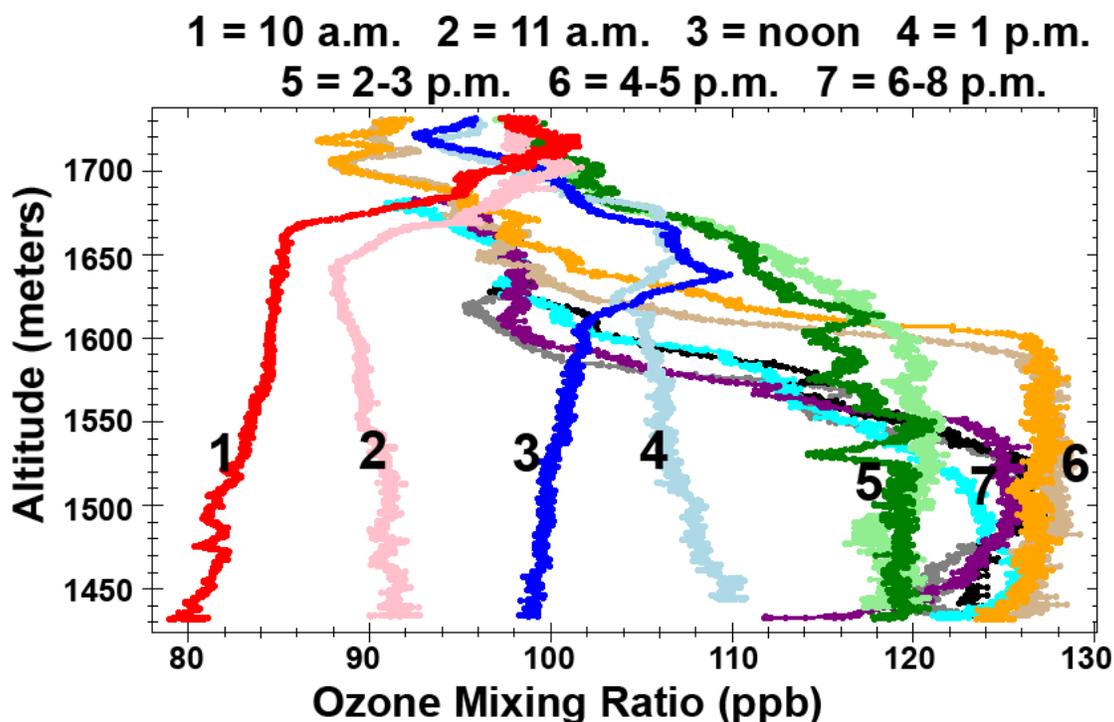
## Exceptionally Elevated Winter Photochemical Ozone Production in the Uintah Basin, Utah

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Exceptionally rapid and high concentration, cold temperature photochemical ozone production occurs in natural gas production fields in Wyoming and Utah in winter at temperatures as low as  $-17^{\circ}\text{C}$ . Sunrise surface ozone concentrations of 10-40 ppb may increase to 140-165 ppb in mid-afternoon in these events. In the winter of 2009-2010, elevated ozone began over  $\sim 15,000\text{ km}^2$  of the sparsely populated Uintah Basin when snow pack was established in mid-December and persisted until the day the snow melted in mid-March. During this 3 month wintertime elevated ozone period, there were 521 hours with hourly ozone concentrations above 75 ppb. In the winter of 2011-2012, there was essentially no photochemical ozone production in the Uintah Basin even though oil and gas production was greater than in the winter of 2009-2010. The difference between the two seasons is that the winter of 2011-2012 in the Uintah Basin was devoid of snow cover. In the winter of 2012-2013 elevated ozone began after snow cover was established in mid-December and lasted until snow melt in the first week in March, 2013. Peak ozone concentrations were in the 165 ppb range. It appears that snow cover aids in the formation of strong temperature inversions that trap ozone precursors such as  $\text{NO}_x$  and volatile organic carbons in a shallow layer near the surface. The snow also reflects solar radiation allowing for a doubling of the energy available for the photochemical production of ozone. Finally, it is speculated that the snow may also be acting as a nocturnal reservoir of nitrous acid that is released at sunrise initiating rapid ozone formation. This wintertime ozone formation is moving the gas fields into Environmental Protection Agency regulatory non-compliance.



**Figure 1.** Ouray, Utah. Ozone production between 10:00 and 17:00, February 2, 2013 within a shallow boundary layer. The ozone at 10:00 was already elevated from the previous day. On February 6 ozone reached 165 ppb.