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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "A high ozone episode in winter 2013 in the Uinta Basin oil and gas region characterized by aircraft measurements" *by* S. J. Oltmans et al.

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The aim of this paper is to present the results of unique measurements of a wintertime high ozone production event. Previous reported wintertime ozone measurements from the Uinta Basin are for surface observations. These airborne measurements provide a 3-dimensional picture of the ozone formation and a number of related constituents that are strongly related to, or are ozone precursors. Based on the reviewer's comments we have eliminated or moved material to a supplemental section, and expanded our analyses.

We have reserved figures covering multiple days to ozone and methane: ozone because its production across the basin is a unique aspect of the reported observations, and methane because of its strong link to ozone precursor NMHCs measured in flask samples collected during the flights. Methane and ozone were measured continuously on the aircraft. Observed tight NMHC/methane relationships allow using methane as a surrogate for ozone precursor NHMCs. The fact that NHMC ozone precursor levels are observed to be elevated across the entire basin is a another unique contribution from this study.

We focus on observational results and analysis of these results in this study and note that several papers that focus on modeling during the winter of 2013 in the Uinta Basin are in the process of publication (Neeman et al., 2014; Ahmadov et al., 2014; Edwards et al., 2014). These papers are noted in the reference list.

Following are unique findings that we highlight in the revised manuscript: 1. The presentation of a set of multiday airborne observations encompassing a geographical basin undergoing large scale wintertime ozone formation. 2. High levels of non-methane hydrocarbons (NMHCs) strongly correlated with methane showing that the strong relationship between NHMCs and methane observed at the surface at Horse Pool (Helmig et al., 2014) was present throughout the Basin. Our data show that the likely source of the methane and NMHCs is the natural gas field in the eastern portion of the Uinta Basin. 3. That elevated ozone and elevated methane are strongly correlated across the basin at relatively lower concentration but at the highest levels of methane (>8 ppm), ozone was not correspondingly elevated. Ozone also increased with increasing CO (indicative of a combustion source with accompanying NO) except in the southwestern portion of the Basin where CO levels were much higher than in other sectors. 4. Profile measurements across the basin showed that the inversion capped boundary layer beneath which the ozone was forming was at a relatively uniform altitude across the Basin independent of surface topography. The top of the boundary layer was a relatively consistent ∼1900-2000 meters above sea level (∼300-

400 meters above ground level). This demonstrates that the source of the high levels of the ozone precursors was beneath the inversion within the Basin as the mountains forming the rim of the Uinta Basin are generally a thousand meters higher than the top of the boundary layer. 5. Ozone and other constituents have the highest mole fractions in a layer from the ground to $\sim$50-200 meters above the surface that is marked by nearly constant temperatures and constituent mole fractions. This layer results from mixing, due to daytime heating, of the surface even though it is snow covered and cold (<-50C). Ozone formation is evident throughout this layer. 6. Methane (and CO) builds up during the first several days of the episode but does not continue to rise in the latter stages of the episode. This is attributed to advection loss of air out of the basin through the top of the inversion. This assertion is based on the observation that there was a gradient layer in which constituent mole fractions decline from the top of the cold mixed layer to above the top of the inversion. Although ozone was also physically lost from the basin, this loss was more than compensated for by the continued photochemical production of ozone that built on the levels of the previous day. Surface deposition to the snow covered ground and nighttime chemical loss were insufficient to negate the continued ozone buildup. 7. A coal fired power plant in the eastern portion of the basin that was once considered a potential source of precursor NOx emissions for wintertime ozone prodcution was shown not to contribute to ozone production in the boundary layer below the height of the power plant exhaust stack.

Responses related to specific comments of Reviewer #1

The inhomogeneity of the precursors is never contrasted to the fairly even distribution of ozone in the valley at the end of the period. We attribute the inhomogeneity of methane to very strong sources in the gas field. Over the rest of the basin, methane and ozone precursor NMHCs are high enough from spreading to produce ozone. We have expanded the discussion pointing out the importance of the source of the precursor NMHCs and that they remain high even when disbursed from their sources.

It appears from the correlation plots (Fig. 12) that the west side is enhanced in heavier

hydrocarbons. Could this be the reason for more ozone being formed there despite lower overall precursors or is the high NO2 in the east sector inhibiting ozone production? It is not clear from the flask sample plots (now Fig. 6) that there is a significant difference in the NMHC composition in the different portions of the basin given the somewhat limited sampling from the flasks. The reviewer raises an interesting point on the impact of the high NO2 levels in the eastern portion of the basin. We have noted the possibility of these high levels inhibiting ozone production near the gas field.

The correlation plots shown in figures 8-10 do not contribute any additional information that cannot visibly be extracted from the color coding of the flight tracks. Figures13 through 15 essentially show ozone buildup over the observational period and the onset of venting on the last day but do not contribute anything else significant to the discussion. We have reduced the number of correlation plots as part of the overall reduction by half in the number of figures. The remaining plots for three key constituents (the rest are now in the supplemental material) on one day (February 2) portray the relationships in the various quadrants with additional specificity that highlights some of the differences between parts of the basin. Assuming that this data will likely be further analyzed with a photochecmial model similar to the Edwards paper for the 2012 campaign, a (significantly shortened) version of this manuscript could be combined with such an analysis. We have chosen to focus on the observational results and analysis of these results in this study and note that several papers that focus on modeling the conditions during the winter of 2013 in the Uinta Basin are in the process of publication (Neeman et al., 2014; Ahmadov et al., 2014; Edwards et al., 2014). These papers, noted in the reference list, also focus on the time period covered by the episode observed during the aircraft measurements.

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 20117, 2014.