Introduction and Methods

The Northern Colorado Front Range (NCFR), including the Denver metropolitan area, was designated an ozone (O3) non-attainment area (NAA) in 2007 for continued exceedances of the 75 ppb National Ambient Air Quality Standard (NAAQS). The NAA covers several highly-populated areas, including Denver as well as the Denver-Aurora-Boulder (DAB) urbanized area with over 21,000 auto owners and Natural Gas (NGM) wells (Fig. 2). O&NG emissions, along with the NIE of the two utilised sites while the majority of the population reside to the S and NE (Fig. 4). Two recent studies (Gilman et al., 2015; Swarthout et al., 2015) concluded that oil and gas relating organic compounds (VOC) emissions could significantly contribute to O3 production in the region. 55%-103% of the O3 production potential in the DIB could be a result of O&NG operations (Gilman et al., 2015). It is estimated that 2.57% of O3 production in the DIB is vented into the atmosphere (Pitkin et al., 2012). This coincides with O&NG emissions dominated elevated O3 in compared to vehicle emissions in the NAA (Thompson et al., 2014). Despite state implemented regulations, the last 14 years of elevated O3 data show no significant trend (Figs. 1: 1-3).

Wind direction to the NCFR is characterized by initially upwind and downwind (Fig. 5). Upwind flow is thermally driven by sun exposure on the Rocky Mountains, and is most prominent during the summer. Denver is exposed to wind from coorider air as the mountains descend to a lower elevation and is the primary driving of transport. This complex behavior makes reactivity modeling difficult. The proposed four factors are the upwind downwind, seasonal dependence, upwind downwind and wind direction to the NCFR (Fig. 5).

Figure 1: Figure 2: Figure 3:

Figure 1: Averaged hourly total diurnal ozone during the summer months from June 1 through August 30. Wind direction data were averaged on a 360 degree scale such that NE-SE is in the DIB, SW-NW in the NCFR.

Figure 2: Figure 3: Figure 4: Figure 5:

Discussion

O3 levels at both sites follow a distinct seasonal cycle with the largest mole fractions recorded in the summer and the smallest in fall (Fig. 9). Winter transport (December through February) of O3 is contributed to by the high latitude source region, with the highest O3 values arriving from the west (Fig. 8). During the fall, O3 values to remain below 50 ppb with the exception of some recorded values in transport from the East. O3 during the spring is elevated relative to the fall and winter. Several O3 exceed 75 ppb resulting from transport from O&NG. O3 values are significantly elevated, transport from the east frequently exceed 80 ppb.

68% of hourly O3 values above 75 ppb occurred during the summer season primarily a result of eastern transport. In the summer, on average, South Boulder shows a ratio of 5.2-pbv/hr to 1 increase in O3, during the early afternoon hours. The rate of increase is -15% higher at BAB as 5.9 ppb/hr (Fig. 8). At South Boulder, O3 in summer transport from the NCFR -10 ppb than arriving from other sectors (Fig. 7). A modeling report from the CDSPE also shows that during the summer, O3 values over the DIB are significantly higher than over the Denver Metropolitan Area (Fig. 8).

From 2005-2012, O3 was above 75 ppb for 279 hours at the South Boulder site and 167 hours at the BAB (Fig. 8). O3 exceed 75 ppb at South Boulder, 6 of these were from the NNE sector. The main source is responsible for 62% of exceedances over 15 of the 167 elevated transport. Evaporating from sources with O&NG operations, hydrocarbons exceed 12% year round at both sites, accounting for 57% of elevated O3 at South Boulder and 72% at BAB, while only 8% of elevated events originated from the Denver metropolitan area.

Conclusion

- Elevated VOC in the DIB results significant O3 production potential based upon calculated O3 reactivity (Gilman et al., 2015; Swarthout et al., 2015). O&NG emissions significantly contribute to elevated VOC in the DIB while vehicle emissions continue to steadily decline.
- Elevated ambient O3 levels in the NCFR are significantly impacted by air transport from local O&NG operations emissions.
- On average, 65% of O3 values above 75 ppb were reported in transport originating from areas of O&NG operations; and only 6% originating from the highly populated Denver metropolitan area.
- This accumulation of observations suggests that emissions from O&NG operations in the DIB have become a large contributor to elevated O3 over 75 ppb in the NCFR.

References


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Influence of Emissions from Oil and Gas Development on Elevated Ozone in the Northern Colorado Front Range

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