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How Much Does Kansas Rangeland Burning Contribute to Ambient Ozone?

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Smoke and Ambient Ozone

One of the major air quality concerns associated with the rangeland burning in the Kansas Flint Hills region is the contribution of smoke to elevated ground level ambient ozone (O_3). For decades, O_3 has been one of the most important air pollutants in the U.S. Exposure to O_3 can impair the breathing of healthy individuals, cause chest pain, headaches, respiratory problems such as pulmonary edema, and aggravate pre-existing asthma and arrhythmia. In past years, the Kansas Ambient Air Monitoring Network has recorded elevated concentrations of O_3 in ambient air during the periods of intensive rangeland burning, and the smoke has contributed to exceedances of the air quality standard for O_3.

Ozone is usually formed through complex photochemical reactions between precursor species such as nitrogen oxides (NO_x) and volatile organic compounds (VOC) under influence of sun light (solar radiation). Both NO_x and VOC are commonly present in rangeland fire smoke. The production of O_3 occurs either in the original smoke plume or as a result of the smoke plume interacting with existing pollutants in the atmosphere.

The New Ozone Standard and the Kansas Ozone Monitoring Network

The standards for O_3 in the National Ambient Air Quality Standards (NAAQS) are evolving. In 2015, the 8-hour O_3 standard was reduced from 75 to 70 parts per billion (ppb). The current Kansas O_3 monitoring network includes nine monitoring sites throughout the state (Figure 1). Three sites are located around the Kansas City area. Three sites are located around the Wichita area and one site is at Topeka. Another site is located at Cedar Bluff reservoir and serves as the background site because the site is not near any significant emission sources. The last monitoring site installed in 2014 is located at Chanute. In general, measurements from all monitoring sites show seasonal patterns, with high O_3 concentrations in summer and low concentrations in winter. High O_3 concentrations are usually observed each year from April 1st to October 31st, which is often referred to as the ozone season.

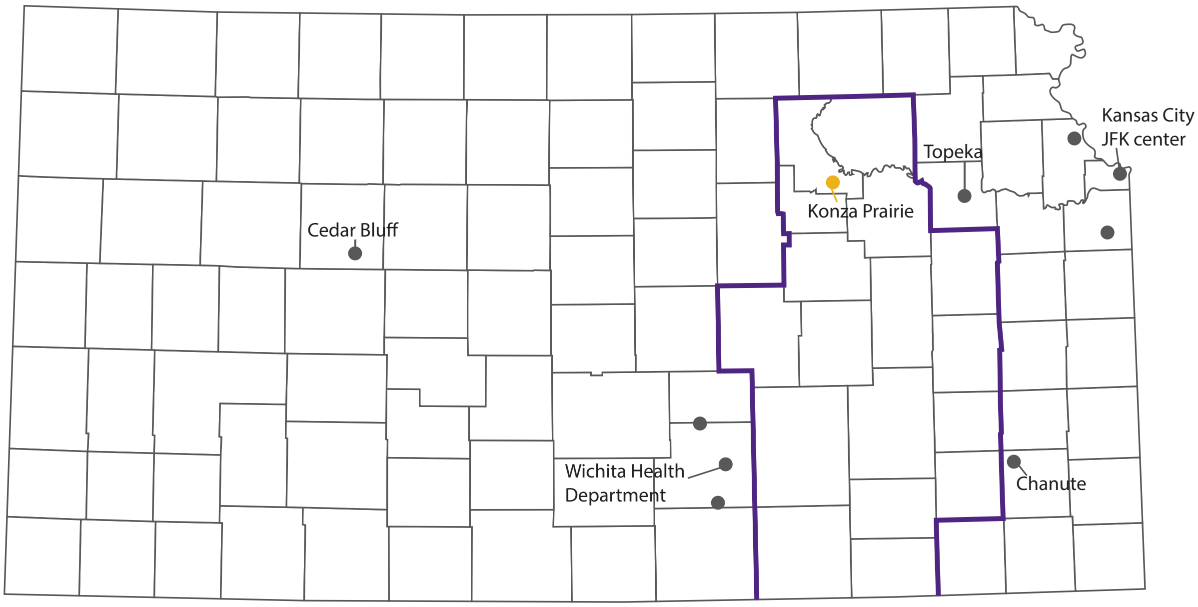

Figure 1. Kansas O_3 monitoring sites (Perimeter of the Flint Hills region is indicated in purple lines; the nine grey dots represent the sites in Kansas O_3 monitoring network; the yellow dot represents the Konza Prairie research monitoring site.)

A design value is a statistic of air pollutant concentrations. It is typically used to describe the air quality status relative to air quality standards and to designate nonattainment areas. The design value of O_3 is the annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years. Based on the calculated design values of O_3 for 2010 to 2014, none of the Kansas monitoring sites show consistent exceedance of the 75ppb O_3 standard; rather it is some special conditions or episodes that pushed the O_3 concentration above the standard (KDHE, 2015). However, as the O_3 standard was reduced from 75 to 70 ppb in 2015, changes in air quality management will likely be required.

Factors that Affect Ambient Ozone

Statistical regression models of daily maximum 8-hour O_3 concentrations were developed at various Kansas sites using meteorological predictors such as solar radiation, temperature, precipitation and relative humidity in air. Seasonal cycle and influence of O_3 from the previous day were also considered in the models. As expected, higher solar radiation, higher temperature, and lower relative humidity correspond to higher O_3 concentrations. The regression models are able to explain more than 70 percent of day-to-day O_3 variation at various Kansas sites.

After the seasonal and meteorological effects were removed from the data, the correlation between O_3 and $PM_{2.5}$ (particles smaller than 2.5 micrometers in diameter) from various sources was recognized. The spikes of O_3 that are not explained by the seasonal and meteorological effect models are significantly correlated with the $PM_{2.5}$ from smoke, the $PM_{2.5}$ from power plant/industrial sources, and the interaction between the two $PM_{2.5}$ sources (Liu et al., 2017).

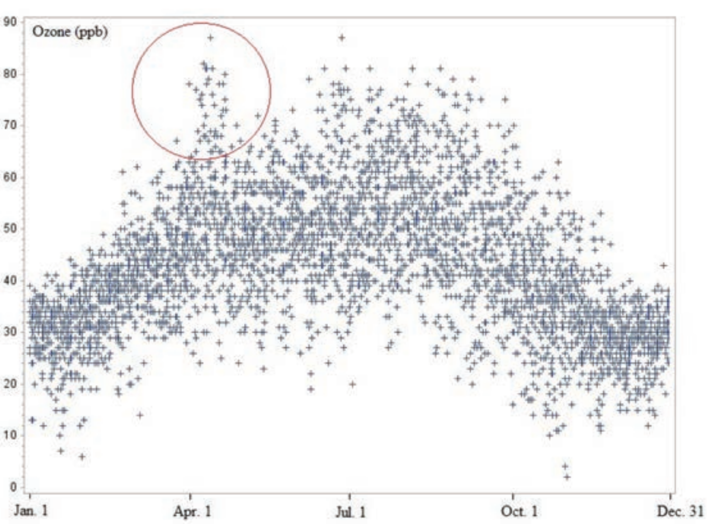

Figure 2. Daily maximum 8-hour O_3 concentrations at the Konza Prairie research site (2002-2013).
(Data points within the red circle are likely associated with smoke emissions.)

Smoke Impact on Local Ambient Ozone

Air quality data from the Konza Prairie research monitoring site (http://www.epa.gov/castnet/) south of Manhattan, Kansas, were used to evaluate the contribution of prescribed rangeland burning to local ambient O_3, because the site is located within the Flint Hills region. Multiple discernable O_3 spikes are observed in April, when intensive rangeland burning occurs in the Flint Hills region, as shown in Figure 2. Without the impact of smoke emissions, the local O_3 concentrations were generally below 63 ppb in April. With the addition of rangeland burning activities, the local O_3 concentrations increased to as high as 87 ppb. From 2002 to 2013, there were 23 days (an average of 2 days per year) which had daily maximum 8-hour O_3 concentration above 70 ppb during the burning season.

Smoke Impact on Ambient Ozone in Downtown Wichita

Wichita Health Department is the urban center monitoring site to measure population exposure in downtown Wichita. In April, the O_3 concentrations in downtown Wichita were generally below 69 ppb without the impact of smoke emissions. Under the impact of smoke, the O_3 concentrations increased to as high as 103 ppb (Figure 3), which was likely due to the combined effects of smoke, mobile, and industrial emissions. From 2001 to 2016, there were 14 days (an average of 1 day per year) that had daily maximum 8-hour O_3 concentrations above 70 ppb during the burning season.

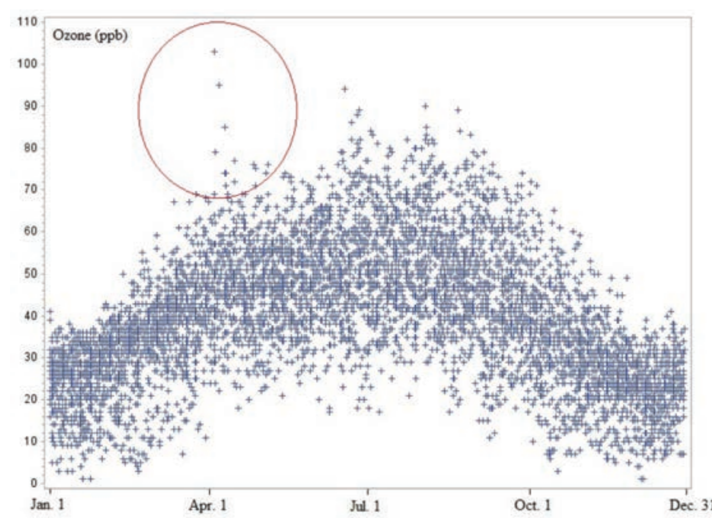

Figure 3. Daily maximum 8-hour O_3 concentrations at the Wichita Health Department site (2001-2016).
(Data points within the red circle are likely associated with smoke emissions.)

Smoke Impact on Ambient Ozone in Downtown Topeka

The Topeka urban center monitoring site measures population exposure in downtown Topeka. In April, the O_3 concentrations in downtown Topeka were generally below 66 ppb without impact of smoke emissions. Under the impact of smoke, the O_3 concentrations increased up to 84 ppb (Figure 4). From 2006 to 2016, there were 6 days that had daily maximum 8-hour O_3 concentrations above 70 ppb during the burning season.

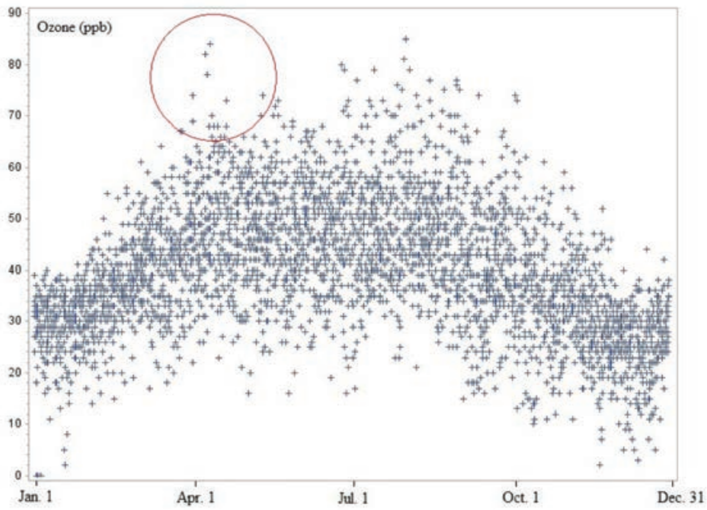

Figure 4. Daily maximum 8-hour O_3 concentrations at the Topeka site (2006-2016).
(Data points within the red circle are likely associated with smoke emissions.)

Smoke Impact on Ambient Ozone in Downtown Kansas City

Kansas City JFK center is the urban center monitoring site to measure population exposure in downtown Kansas City. In April, the O_3 concentrations in downtown Kansas City were generally below 63 ppb without the impact of smoke emissions. Under the impact of smoke, the local O_3 concentrations increased up to 76 ppb (Figure 5). From 2001 to 2016, there were only 5 days that had daily maximum 8-hour O_3 concentrations above 70 ppb during the burning season.

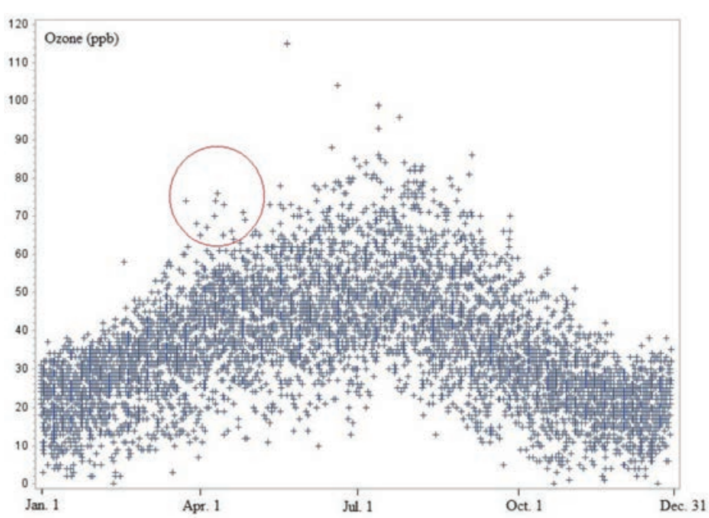

Figure 5. Daily maximum 8-hour O_3 concentrations at the Kansas City JFK site (2001-2016).
(Data points within the red circle are likely associated with smoke emissions.)

Summary

Smoke from Kansas rangeland burning affects ambient O_3 concentrations in and near the Flint Hills region. During the burning season, smoke increased the O_3 concentrations in local environments from below 63 ppb to as high as 87 ppb. Smoke also contributed to elevated O_3 concentrations in urban areas such as Wichita, Topeka, and Kansas City. Smoke impacts on these cities are largely episodic and only occurred under certain weather conditions. Wichita had relatively higher background O_3, and thus has a higher chance of O_3 exceedance under the influence of smoke. Smoke may react with local pollutants in Wichita and increase O_3 concentrations to as high as 103 ppb. The smoke impact on Kansas City was relatively low due to its further distance (120 miles) from the Flint Hills region.

Managing Smoke to Reduce Impact on Ozone

The smoke impacts on populated cities may be reduced through proper timing of burning. The following considerations should help land managers determine whether burning should occur and the size of the area to be burned to reduce the impact of smoke.

1. The online smoke screening tool at ksfire.org website can be used to predict where the smoke from a particular location will travel and whether it will affect concerned communities based on forecasted wind direction and other weather conditions.
2. When poor air quality conditions are observed or are forecasted in areas that may be affected by smoke, a burn should be rescheduled to avoid making the conditions worse. For example, if today's O_3 level is already high, and tomorrow's weather conditions (e.g. strong solar radiation and high temperature) are likely to promote O_3 formation, the next day burn would need to be rescheduled. Practical O_3 forecasting tools are under development at K-State to assist smoke management under the new O_3 standard.

References

KDHE. 2015. 5-Year Ambient Air Monitoring Network Assessment. Kansas Department of Health and Environment. Bureau of Air.

Liu, Z., Liu, Y., Murphy J., and Maghirang R. 2017. Estimating Ambient Ozone Effect of Kansas Rangeland Burning with Receptor Modeling and Regression Analysis. Environments. (4)14; doi:10.3390.

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MF3357 June 2017