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P552 The climatological character of air pollution events in the central Plains states

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1. INTRODUCTION

With the industrialization of the United States, atmospheric pollutant concentrations have been on the rise and problems associated with these pollutants have also been on the rise. These pollutants come from many different sources, both point and mobile, and cause a variety of problems with both human and environmental health. One such pollutant is ground level ozone, which has become a problem in many cities across the United States.

According to the United States Environmental Protection Agency (EPA) (2003), about one in every three people in the United States is at a high risk of experiencing some of the problems associated with ground level ozone. Everyone who is active outdoors is at risk of experiencing these problems due to the fact that ozone is able to penetrate deeper into the more vulnerable parts of the lungs during physical activity (2003). One group that is at high risk is active children, which is due to the fact that kids often spend a large part of their summers playing outdoors and they may experience the health effects of ground level ozone at more moderate levels of outdoor activity or at lower ozone levels than the average person (2003). Several studies have been done on the health effects of ozone exposure. A three-year study by Frischer et al. (1999) investigated the long-term effects of ambient ozone on lung function in children and they found that long-term ambient ozone exposure might negatively influence lung function growth. Other studies by Burnett et al. (1994) and White et al. (1994) were consistent in showing an association between high levels of ambient ozone and an increase in hospital admissions, particularly for asthma.

Studies have shown that certain atmospheric conditions are favorable for the formation of ground level ozone. Niemeyer (1960), Holzworth (1964 & 1967), and Miller (1967) have shown that these favorable atmospheric conditions include stable conditions, low wind speeds, low mixing heights, temperature inversions, clear skies, and a large amount of incoming solar radiation. Forecasts of these favorable conditions coupled with measurements of air quality could provide a basis for pollution control and mitigation of its impacts (Niemeyer, 1960). A forecast of unfavorable atmospheric conditions could help alert interested parties to take precautionary measures.

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This study will focus on the air quality of Missouri in the attempt to set a basis for the above-mentioned forecasting of favorable conditions. The main purpose of this study is to analyze the atmospheric conditions that are associated with high concentrations of ground level ozone in Missouri. The main objective is accomplished in two ways. First, an Air Quality Index (AQI) is created for three major cities in the state of Missouri. These cities are St. Louis, Kansas City, and Springfield. This part will help to give an understanding of when high ozone concentrations occur in these areas and for the state of Missouri. Second, synoptic weather patterns, which are favorable for the formation of ground level ozone in the state of Missouri, are determined and classified, because synoptic weather features have been shown to contribute to high pollution concentrations in the areas that they influence.

2. METHODS AND ANALYSES

2.1. Analyses

The air pollution data used in this study were ten-year sets (1998 to 2007) of average hourly ground level ozone concentrations for the cities of Kansas City, Springfield, and St. Louis. The concentrations were measured in parts per million (ppm) for each station. For each year, the data set ran from the beginning of April to the end of September. This time frame was chosen due to the fact that it covers the warm seasons for the state of Missouri when most high pollution days occur. The ozone data were obtained from the Missouri Department of Natural Resources (MODNR).

Weather data used in this study was obtained from archived weather maps. The 12Z surface pressure maps were obtained from the National Oceanic and Atmospheric Administration (NOAA) Central Library U.S. Daily Weather Maps Project. From these maps, wind speeds, wind directions, synoptic weather features, and flow patterns for the surface were taken for each specific high pollution day.

2.2. Methods

An Air Quality Index for ground level ozone was created using the procedure outlined in the EPA's *Guidelines for the Reporting of Daily Air Quality – the Air Quality Index* (2006). An index value was found for each day and monitoring site involved in the study. The first part of this process involved converting the averaged hourly ground level ozone levels to averaged daily values. Averaged daily values were calculated by selecting the highest continuous 8-hour average for each day. Kansas City, St. Louis, and Springfield are only required to report 8-hour concentrations in accordance with EPA guidelines. For this reason, the 8-hour average was favored over the 1-hour average. The 8-hour average then became the daily average ozone concentration for each monitoring day. Next, averaged daily values were converted to their associated index values. This was completed using US EPA standards found in the EPA's *Guidelines for the Reporting of Daily Air Quality – the Air Quality Index* (2006). The standards are set forth in an equation that is used to compute the index values. Equation 1 shows the equation used by the US EPA to convert concentration values into index values.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo} \qquad (1)$$

Where:

I_p = the AQI value for the pollutant
C_p = the rounded concentration calculated for the pollutant
BP_{Hi} = the breakpoint value that is greater than or equal to C_p
BP_{Lo} = the breakpoint value that is less than or equal to C_p
I_{Hi} = the AQI value corresponding to the break point value greater than or equal to C_p
I_{Lo} = the AQI value corresponding to the break point value less than or equal to C_p.

The equation uses breakpoint values to discern when certain values should be used in the equation based on the concentration of ozone found in the area. Breakpoint values are assigned values that represent a certain category a pollutant concentration can fall into. If the pollutant falls into the category, the numbers at the high end and low end of the breakpoint category are used in the equation. The numbers that were used in the equation were based on the concentrations found using the 8-hour daily average. Table 1 shows the breakpoint values and index values used in the calculation of the index value for each ground ozone level concentration.

Table 1: Breakpoint concentration levels and the associated. AQI values used in the equation.

O3 (ppm) 8-hour	AQI	Category Description
0.000 – 0.064	0 – 50	Good
0.065 – 0.084	51 – 100	Moderate
0.085 – 0.104	101 – 150	Unhealthy for Sensitive Groups
0.105 – 0.124	151 – 200	Unhealthy

After the AQI values were calculated, they were assigned color values based on which air quality category the values fell into. This helps make days with high pollution levels easily discernable from days with low pollution levels for the public. Table 2 shows the color scheme used to describe the calculated index values for ozone.

Table 2: Color schemes and category description for different AQI categories.

AQI	Category Description	Color
0 – 50	Good	Green
51 – 100	Moderate	Yellow
101 – 150	Unhealthy for Sensitive Groups	Orange
151 – 200	Unhealthy	Red

Days with an AQI value of 50 or above were used in the classification process. For each day that fell into the above category, 12Z surface pressure maps were analyzed. During the map analysis, Missouri was set as the center reference point for each of the maps. Locations of synoptic weather features were noted with respect to Missouri. Wind flow patterns at the surface were examined and the direction of the flow was noted. After the synoptic weather patterns were noted at the surface pressure level, the high ozone days were then placed into different categories. At the surface, each day was placed into a category based on the location of a high-pressure system with respect to Missouri. Each category was then analyzed to determine how they are linked to high ozone levels in Missouri. After each surface category was found for high ozone days, they were compared to days when ozone concentrations were lower than the threshold values. Percentages of the number of occurrences of each category for high and low ozone days were found in order to determine a frequency of when each category was associated with a high pollution day or a low pollution day. This was done for five years of the study period, 2003 through 2007. This information will help to set an even stronger basis for potential high pollution day forecasting in Missouri.

3. Results

3.1 AQI

After the Air Quality Index was calculated for each city, a total of 555 days with high ground level ozone concentrations were found in the ten-year study period. These 555 days represent days in which ground level ozone concentrations equal to or exceed the "moderate" (yellow) level of the US EPA's Air Quality Standards. During the ten year period, only 58 of the days fell into the "unhealthy for sensitive groups" (orange) category. While, only two days fell into the "unhealthy" (red) category. The other days left over of the 555 days fell into the "moderate" (yellow) category. The rest of the days left in the ten year period fell into the "good" (green) category and were not used in the study, while the 555 days that fell above the "moderate" (yellow) category were used in this study. Fig. 1 shows the total number of days that fall into each AQI category.

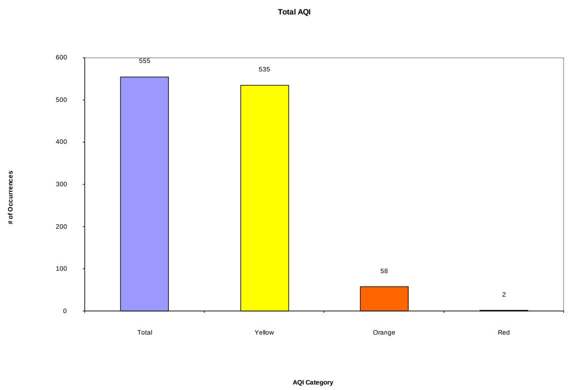

Figure 1: Total number of days that fall into each AQI category for the study period.

3.2 Classification

Synoptic scale surface features have been shown to influence the occurrence of high ozone days in large cities. For this study, these surface features were put into categories based on the position of high-pressure systems around the state of Missouri. High-pressure systems, particularly when Missouri is located on the backside of a high, seem to be the most favorable for high ground level ozone days in the state. At the surface, six categories were found to exhibit an influence over causing high ground level ozone days. The six surface categories include: High-pressure system to the North of Missouri, High-pressure system to the Northeast of Missouri, High-pressure system to the East of Missouri, High-pressure system to the Southeast of Missouri, High-pressure system to the South of Missouri, and High-pressure system over Missouri. Each category has a different effect on the surface flow patterns and weather for Missouri. Fig. 2 through 7 show each surface category found in the study.

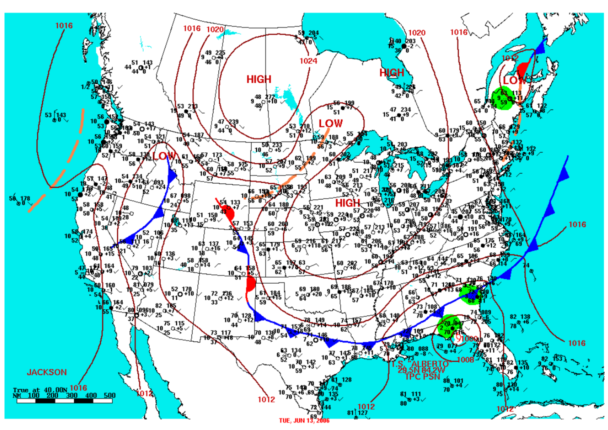

Figure 2: High pressure system located to the North of Missouri. Surface pressure measured in hPa with contours every 4hPa. Map from Tuesday, June 13, 2006.

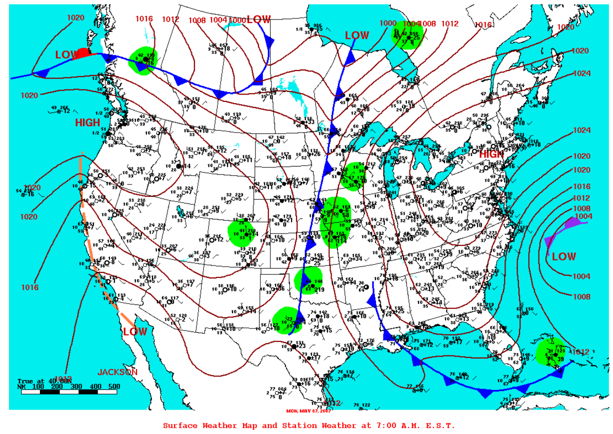

Figure 3: As in Fig. 2, except for the high pressure system being located to the northeast of Missouri. Map from Monday, May 7, 2007.

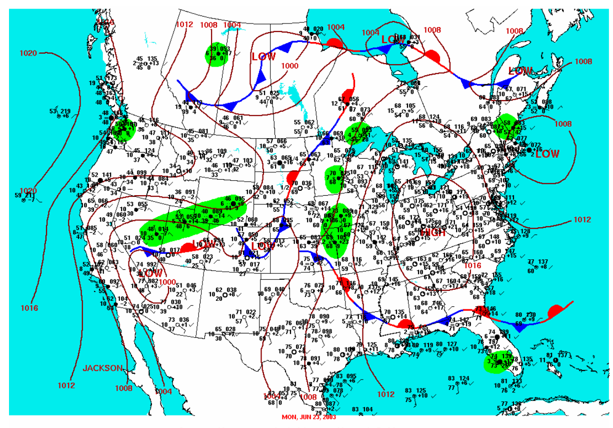

Figure 4: As in Fig. 2, except for the high pressure system being located to the east of Missouri. Map from Monday, June 23, 2003.

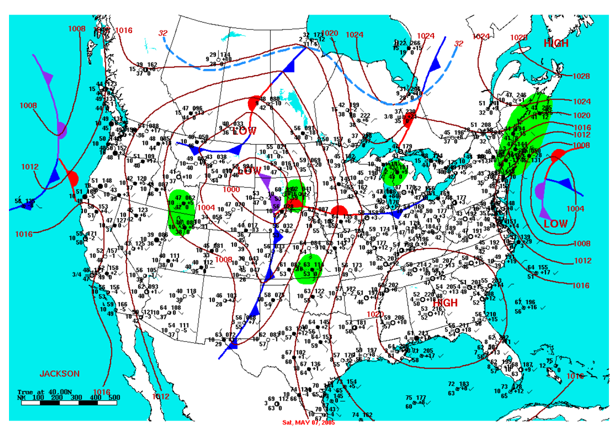

Figure 5: As in Fig. 2, except for the high pressure system being located to the southeast of Missouri. Map from Saturday, May 7, 2005.

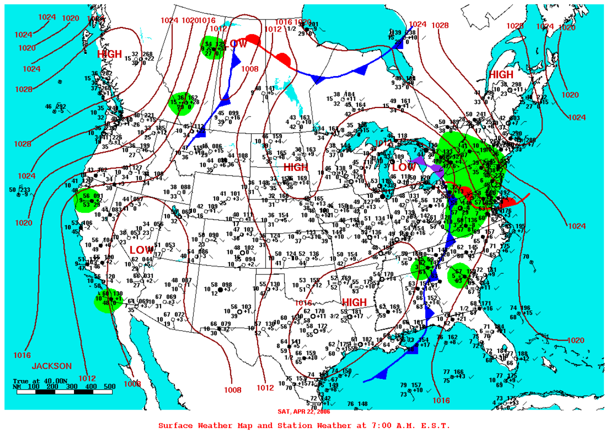

Figure 6: As in Fig. 2, except for the high pressure system being located to the south of Missouri. Map from Saturday, April 22, 2006.

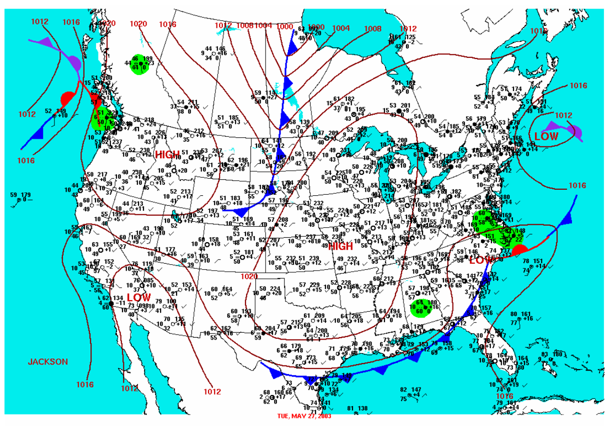

Figure 7: As in Fig. 2, except for the high pressure system being located over Missouri. Map from Tuesday, May 27, 2003.

3.3 Rate of Occurrence

During the last five years of the ten-year study period, no high pressure system being present had the largest rate of occurrence. It occurred 32% of the time during the five-year period. A high-pressure system to the Northeast of Missouri had the second largest rate of occurrence at 23% of the time. A high-pressure system to the North, East, and Southeast of Missouri had similar rates of occurrence, which hovered around 10% of the time. A high-pressure system to the South and Over Missouri had the lowest rates of occurrence at around 5% of the time. These rates of occurrence take into account both days with high ozone concentrations and days with low ozone concentrations. In total, a specific surface category could have taken place on 915 possible days during the five-year study period. Fig. 8 shows the percent rate of occurrence for each surface category during the five-year examination period.

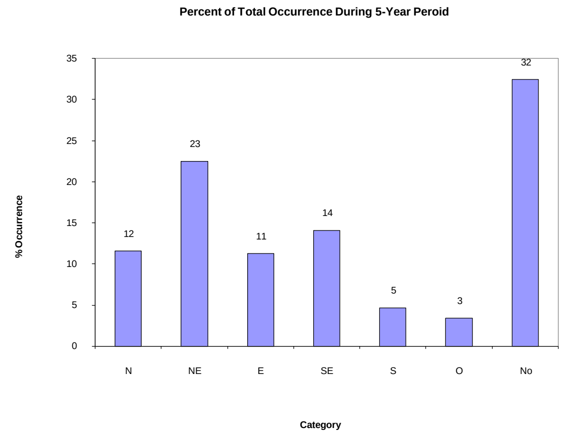

Figure 8: Percent rate of occurrence for each surface category during the last five years of the ten-year study period.

Also during this five-year period, no high pressure system being present was associated with the largest rate of causing low concentrations of ground level ozone. During this category, 90% of the time that this occurred it was associated with a low ozone concentration. Only 10% of the time that it occurred it was associated with high ozone concentrations. Similar patterns can be seen in the categories consisting of a high to the North and to the Southeast. During these categories, roughly 80% of the time they occurred they were associated with a low ozone concentration. Only 20% of the time they occurred were they associated with high ozone concentrations. The other surface categories had around the same rate of occurrence of high and low ozone concentrations. Roughly 50% of the time they occurred they were associated with a high ozone concentrations. The other 50% of the time they were associated with low ozone concentrations. Fig. 9 shows the percent rate of occurrence of high and low ozone concentrations for each surface category.

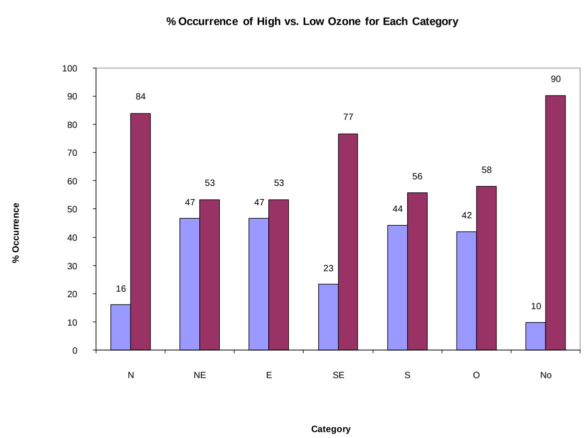

Figure 9: Rate of occurrence of high or low ozone concentrations for each surface category for the last five years of the ten year study period. (Blue represents high ozone, Purple represents low ozone)

4. SUMMARY AND CONCLUSIONS

The main purpose of this study was to analyze the atmospheric conditions that are associated with high concentrations of ground level ozone in Missouri. This main objective was accomplished in two ways. First, an Air Quality Index was created for three major cities in the state of Missouri. Second, synoptic weather patterns, which are favorable for the formation of ground level ozone in the state of Missouri, were determined and classified.

After the Air Quality Index was calculated for each city, a total of 555 days with high ground level ozone concentrations were found in the ten-year study period. During the ten year period, only 58 of the days fell into the "unhealthy for sensitive groups" (orange) category. While, only two days fell into the "unhealthy" (red) category.

The six surface categories included: high-pressure system to the North of Missouri, high-pressure system to the Northeast of Missouri, high-pressure system to the East of Missouri, high-pressure system to the Southeast of Missouri, high-pressure system to the South of Missouri, and high-pressure system Over Missouri. When analyzed, the times when no high was present were linked to the highest percentage of low ozone days, while other categories including highs to the Northeast, East, South, and Over Missouri seemed to have a 50% chance of being linked to a high ozone day. Highs to the North and Southeast of Missouri were linked to only a small rate of occurrence of high ozone days.

Based on the results discussed above, several general conclusions can be made.

- Overall, Missouri has good air quality. When an AQI was created, there were only a few days that fall into the orange-level category for the whole ten-year period. There were even fewer days that reached the red-level. In the beginning, this study intended on using just using days that fell into the orange-level, however, there were not enough of them to make any determinations. The threshold was then lowered to the yellow-level to incorporate a larger data set into the study. Most of the days used in this study are high ozone days, but they are not considered high enough to cause health problems.
- Another conclusion that can be made is the fact that the synoptic flow patterns that are associated with high ozone concentrations can be put into categories using an environment to circulation approach. This process offers a viable way to determine which type of surface flow patterns are associated with high ozone days in Missouri. This process may be a viable option for determining the atmospheric features that are associated with high ozone concentrations in other areas around the world.
- The times when no high pressure system occurred were found to have a high rate of being associated with low ozone days, 90%. This is primarily due to the fact that this type of situation contains conditions that are not favorable for the formation of ground level ozone, such as high winds, high mixing heights, and high ventilation rates.
- For the five-year period analyzed, most categories had a 50% chance of being associated with a high or low ozone day. This means that most of these surface categories have a good chance of causing a high ozone concentration somewhere in Missouri when they occur. A larger data set may need to be analyzed in order to give a more accurate percentage of how often each surface category causes a high ozone concentration.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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