The Straight Line on Bad Ozone

Ozone and Smog

Not all ozone is created equal. "Good" ozone is that which occurs naturally in the stratosphere and protects us from damaging ultraviolet radiation from the sun. "Bad" ozone is that which forms near the Earth's surface as the main ingredient of smog. While good and bad ozone are chemically identical (formula O_3), it is their location that sets them apart. Ground-level ozone is bad because it causes adverse health effects in humans and other living organisms.

Smog forms out of a chemical "soup" in the lower atmosphere and is sometimes called *photochemical smog* to distinguish it from other types of haze that occur when fog combines within emissions like those from burning coal. The type of smog that contains ozone is created when oxides of nitrogen (NOx) react with volatile organic compounds (VOCs) in the presence of sunlight and higher air temperatures. The NOx and VOCs are examples of *primary pollutants*, which come from automobiles, industry, and a variety of other sources. Their interactions create many different and hazardous *secondary pollutants* such as ozone.

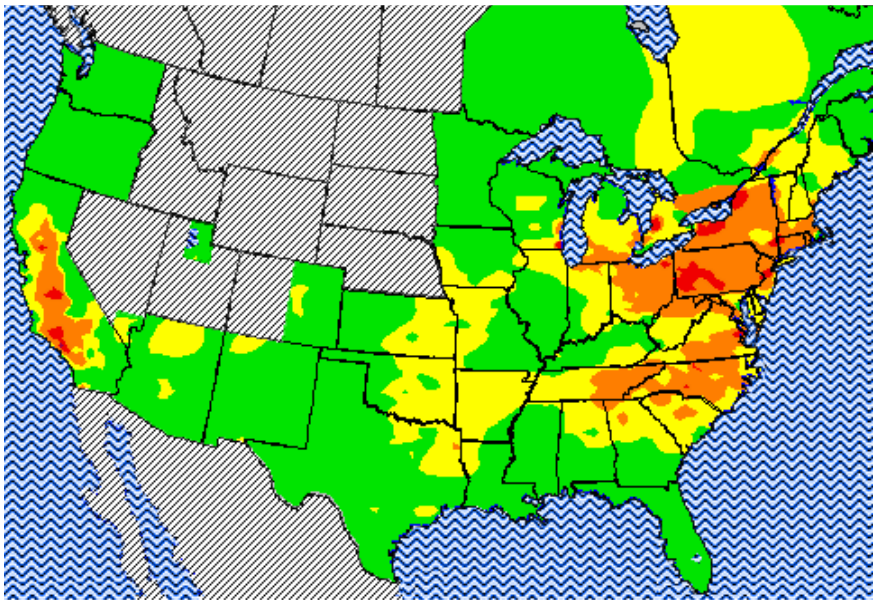
Ozone and Health Effects

The health consequences of ground-level ozone are widely recognized. The harmful effects of ozone come from the fact that it is a strong *oxidizer*. Oxidizers work by chemically attacking other substances, including plant and animal tissues and any number of synthetic materials. Ozone can damage crops, cause eye irritation, and promote respiratory problems. The U.S. Environmental Protection Agency has published two informative brochures on the origin and effects of ground-level ozone, titled *Ozone and Your Health* and *Smog – Who does It Hurt?* They can be viewed and downloaded at these websites:

http://www.epa.gov/airnow/ozone-c.pdf
http://www.epa.gov/airnow/health/smog.pdf

Air Quality Index

The EPA has developed a system for reporting the severity of ozone levels called the Air Quality Index (AQI). The index is derived from anticipated health effects at different ozone concentrations. The AQI is color-coded to make it readily understandable and to allow the creation of maps that display air quality at a glance. The map shown here was for August 11, 2002.



Everyone is susceptible to the damaging effects of ozone, but some groups of individuals are more sensitive to ozone than others. Even young, healthy athletes are harmed by elevated ozone levels. Because athletes breathe more deeply during heavy exertion, expanding the lungs and taking in greater amounts of air, ozone is able to reach tissues that are susceptible to injury. Damage can occur even at lower ozone levels if the exercise is especially vigorous or prolonged.

What can individuals do to protect themselves from ozone?

- Become informed about the potential health effects of exposure to ozone.
- Check ozone levels and forecasts, particularly during periods of warmer weather. News media and state agencies are possible sources of this information. Current and predicted ozone levels can be found at EPA's AIR*Now* website (http://www.epa.gov/airnow/) from May through September each year.
- Reduce outdoor activity and avoid unnecessary exertion when ozone levels are likely to be harmful. Plan those activities for times when ozone levels are lower.
- Avoid unnecessary use of automobiles and other gas-driven engines that contribute to smog.

The Meteorology Connection

Look again at the AQI map on the preceding page. August 11, 2002, was a relatively bad day for air quality over much of the U.S. and Canada. In fact, that August was one of the worst months in recent years for ozone levels.

How does weather play a role in the creation of poor air quality periods? It is a fact that warm temperatures are needed to trigger the photochemical reactions that cause smog, but temperatures are only part of the answer. The conditions that create hot summer weather also favor the build-up of ozone levels, namely, almost stationary high-pressure systems that extend for days or even weeks at a time. Prevailing wind patterns also affect air quality, this being more of a problem for certain regions of the country than others during the summer season. Some relatively pristine areas of the country suffer from poor air quality at times when airborne pollutants are carried in from other regions.

Discussion points:

- What are the prevailing winds in our region, and how do they vary with the seasons?
- How do wind patterns affect air quality in our region at different times of the year?
- On the August 11, 2002, map, where are the higher ozone levels located? Are the locations consistent with what would be expected?
- How can the air quality level in northern Quebec, Canada, be explained?
- Why are there no data for most of the Rocky Mountain States?
- Why is New England sometimes called the "tailpipe" of the country?

It should be apparent from these discussions that temperature and wind conditions are important factors in determining ozone levels. High temperatures and stagnant or low-wind-speed conditions favor the formation and build-up of ozone levels wherever the chemical ingredients for smog are present. How strong is the association between temperature and ozone levels, and between wind speed and ozone levels? The following real-data activity looks for correlations between these variables.

Real-Data Activity

Overview: Obtain online climate data and Air Quality Index values from U.S. Government agency data archives. Arrange the data in a table and then graph the data to look for correlations.

Data Sources:	NOAA National Climatic Data Center, http://lwf.ncdc.noaa.gov/oa/climate/climatedata.html#DAILY
	EPA AIR*Now* AQI Map Archives http://www.epa.gov/airnow/mapselect.html
Parameters:	Maximum temperature (^{o}C) Mean wind speed (mph) 1-Hour peak ozone concentration range (ppb)
Location:	Harrisburg, PA
Dates:	August 1-31, 2002

Procedure

1. Go to the NOAA website and click on “Surface Data: Daily”
2. Click on “Global and U.S. – Select by Station”
3. Read the NOAA policy and agree to the terms of use.
4. Select “Display Two Parameters for One Station” and click on the U.S. on the world map.
5. Select “Pennsylvania” and continue.
6. Select “Harrisburg Capital.” Select “Maximum Temperature” and “Mean Wind Speed” as the two parameters. Select “August” and “ 2002.” Select “Parameters on Separate Graphs.” Click on “Submit Graph Values.”
7. View the data to see the daily variations in temperature and wind speed. Notice the range of values for each parameter.
8. Click on “To Download the Data File Click Here!”
9. Copy the data into the blank spaces in the table provided, or create an entirely new table for the data.

10. Go to the EPA website and click on the Northeast Region on the map.

11. Select “August” and “2002” and “Ozone.” Click on “See Map Archives.”

12. The thumbnail ozone maps provide a quick view of changes in ozone levels for the entire month. Look for patterns in the rise and fall of ozone levels over periods lasting several days. Similar patterns tend to recur throughout the warmer months of the year.

13. To see particular values for Harrisburg, PA, click on each daily map. Use the AQI map legend to determine the ozone concentration ranges (in parts per billion) and record those values in the table.

14. When all of the data have been recorded, plot the values on the two prepared graphs. The first graph shows ozone level vs. temperature, while the second graph shows ozone level vs. wind speed. Place a small **x** in the correct box for each of the 31 data pairs in each graph. Since these graphs are intended to be scatter plots, do not try to connect the graphed points.

15. Study the scatter of data in each graph. Is there any trend in the data, or are the data points simply spaced about in random fashion? If a trend emerges, it would signify some degree of correlation between the two variables in the graph. In other words, one variable appears to be related to the other. Associations of this type may imply a cause-effect relationship, but that is not always the case. (For example, a scientific study might reveal that people who wear glasses prefer the color green, but such a finding would not say anything about cause and effect.) If there is a discernible trend in either graph, draw a “best fit” line through the plotted points.

16. Answer the following questions:

    a. Describe the scatter of data in the graph of ozone versus temperature. Is there any trend in the data? If so, explain how the two variables appear to be related.

    b. Answer the same question for the graph of ozone versus wind speed.

    c. What are possible explanations for any observed relationships?

Meteorological Data and Ozone Levels

Harrisburg, PA
August 2002

Date	Maximum Temperature (^{o}F)	Mean Wind Speed (mph)	1-Hour Peak Ozone Concentration Range (ppb)
1			
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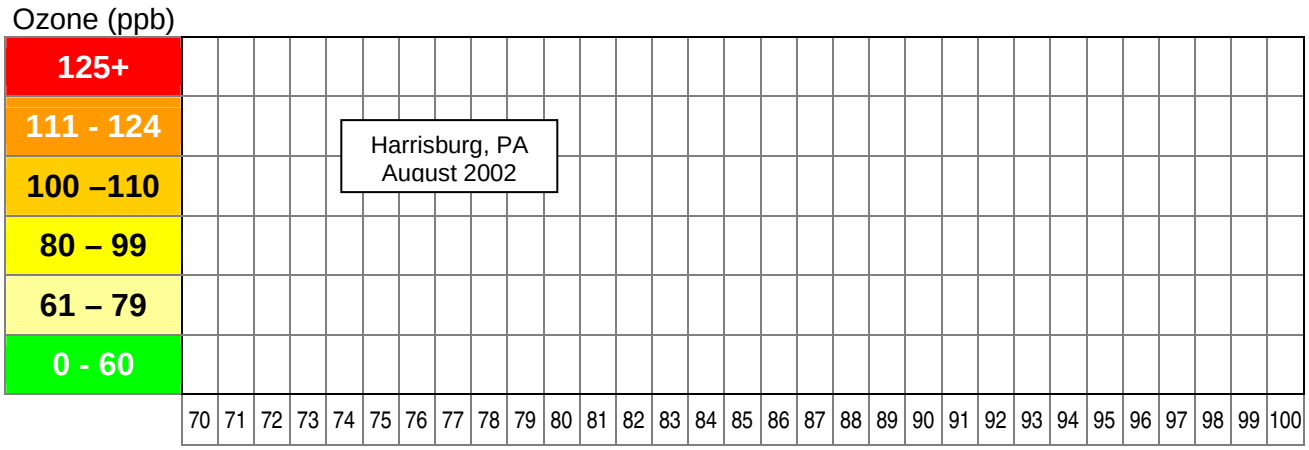
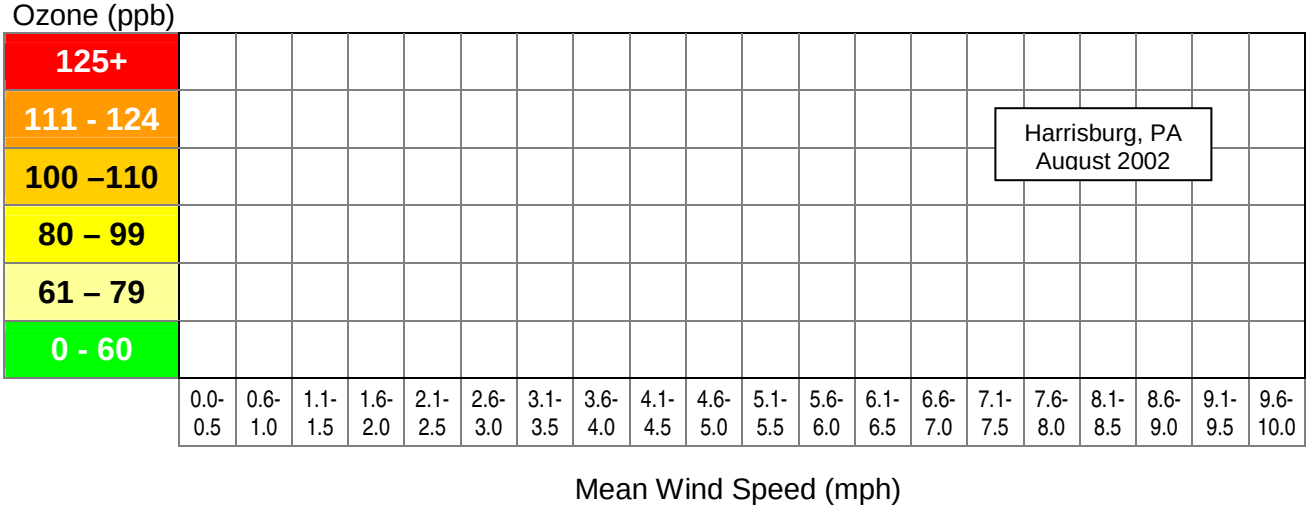
1-hour Average Peak Ozone Concentration vs. Maximum Temperature



1-hour Average Peak Ozone Concentration vs. Mean Wind Speed



THE STRAIGHT LINE ON BAD OZONE 

Teachers' Notes

Objectives: Students will understand the distinction between "good" and "bad" ozone. They will strengthen their awareness of the adverse health effects of ground-level ozone and learn of ways to protect their health when ozone levels are elevated. They will consider meteorological factors related to ozone levels and will look for correlations in real data sets.

Grade Level: High

NSES: A5, A6, B8, B9, D4, D7, E6, E7, F6, F7, F8, F11, F13, F14, F15

NHSCF: 1a, 4b, 4c, 6a, 6b, 6c

Key Concepts

Although the terms "good" and "bad" are applied to ozone, the usage is somewhat misleading, since all ozone is chemically identical. What is actually good or bad is the *location* in which ozone is found. Ground-level ozone, produced in the chemical interactions that constitute smog, has been associated with respiratory problems and other adverse health effects in humans. Because it is a strong oxidizer, ozone can be damaging to living tissue and many other natural and synthetic substances if the amount or duration of exposure is sufficient.

Most students will be familiar with air quality alerts issued during times of elevated ozone concentrations ("bad air" days). Young people, who are generally more robust than the rest of the population, may tend to believe that such warnings do not apply to them. In fact, ozone can be damaging to any person of any age. Students who participate in strenuous physical activities when the Air Quality Index is high are probably causing themselves more harm than good. Parents and coaches may show similar lack of understanding or disregard of the risks.

High surface temperatures promote ozone formation when the proper chemical ingredients are present. Primary pollutants contributing to smog are present in abundance within large metropolitan and industrial regions of the U.S. Because cities tend to be hotter in the summer and retain the day's heat longer, the urban microclimate exacerbates the problem of ozone formation and associated health effects. With rising global temperatures, there is concern that air quality will further deteriorate and cause yet a higher incidence of health problems in the future. An informative overview of the potential impacts of climate change on human health is available at this website:

http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewhealth.htm

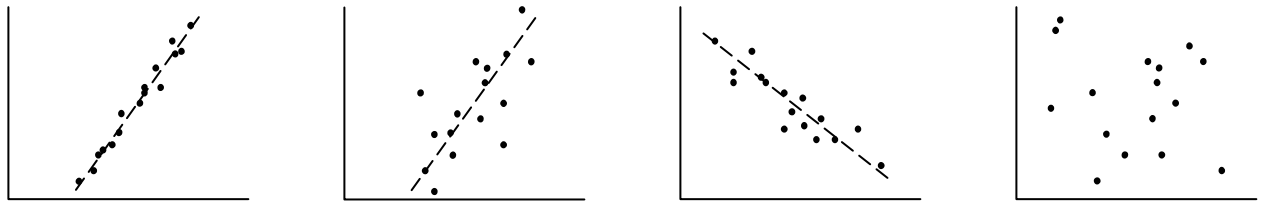
When visiting this website, scroll down the page to see the graphs of ozone concentration vs. temperature for New York City and Atlanta. The graphs illustrate clearly the correlation between the two parameters and mirror the findings of the real-data activity presented to students herein.

The problem of bad air days is not limited to the urban scene – even remote areas are vulnerable to smog. Many national parks and forests suffer from reduced visibility and poor air quality caused by the migration of smog from source areas. EPA's AIR*Now* provides web cameras that show visibility at several locations in real time, including views of Mount Washington in New Hampshire and Acadia National Park in Maine. See the webcam images at http://www.epa.gov/airnow/webcam.html.

EPA's Air Quality Index is a simplified means of reporting ozone levels. The following table describes the relationship between index values and ozone concentrations.

Ozone Concentration (ppm) (8-hour average, unless noted)	Air Quality Index Values	Air Quality Descriptor
0.0 to 0.064	0 to 50	Good
0.065 to 0.084	51 to 100	Moderate
0.085 to 0.104	101 to 150	Unhealthy for Sensitive Groups
0.105 to 0.124	151 to 200	Unhealthy
0.125 (8-hr) to 0.404 (1-hr)	201 to 300	Very Unhealthy

In the real-data activity, students are asked to graph a series of data pairs for ozone level and temperature and for ozone level and wind speed, and then to look for correlations. Some students may be unfamiliar with scatter plots and the meaning of correlation. Showing examples like the ones below may help to clarify any confusion about the meaning of the terms and interpretation of the graphs.



Positive Correlation (Strong) | Positive Correlation (Weak) | Negative Correlation | No Correlation

For additional information on ozone and health, visit these websites:

http://www.airinfonow.org/html/ed_ozone.html
http://royal.okanagan.bc.ca/mpidwirn/atmosphereandclimate/smog.html
http://www.atmos.umd.edu/~owen/CHPI/IMAGES/o3effecs.html

ANSWER KEY

Discussion points:

- What are the prevailing winds in our region, and how do they vary with the season? ***In New England the prevailing winds are from the northwest during the winter months and from the southwest during the summer months. However, the region is notorious for its variable weather conditions, and winds can come from any direction at any time of the year.***
- How do wind patterns affect air quality in our region at different times of the year? ***Prevailing winter winds bring clean Arctic air to New England. However, westerly airflows tend to carry pollution to New England from the industrial Midwest states. Similarly, moist summer airflows bring pollution to our region from large metropolitan areas to the south and southwest.***
- On the August 11, 2002, map, where are the higher ozone levels located? Are the locations consistent with what would be expected? ***Higher ozone levels coincide fairly closely with regions of greater population density and industrial activity, as would be expected.***
- How can the air quality level in northern Quebec, Canada, be explained? ***The ozone could not have originated in northern Quebec, which is very sparsely populated. Air pollutants that migrated from more southerly locations in Canada and the U.S probably caused the observed air quality levels.***
- Why are there no data for most of the Rocky Mountain States? ***Most of this area is remote and lightly populated and consequently does not experience air quality problems to the same extent as more urbanized parts of the country. There is no great need for ozone monitoring in most of this region.***
- Why is New England sometimes called the “tailpipe” of the country? ***New England is on the receiving end of airflows coming from large urban and industrial areas to the south and west. The degradation in air quality is most acute during the peak summer months and affects even the northern forests and mountaintops of New England.***

ANSWER KEY

16. Answer the following questions:

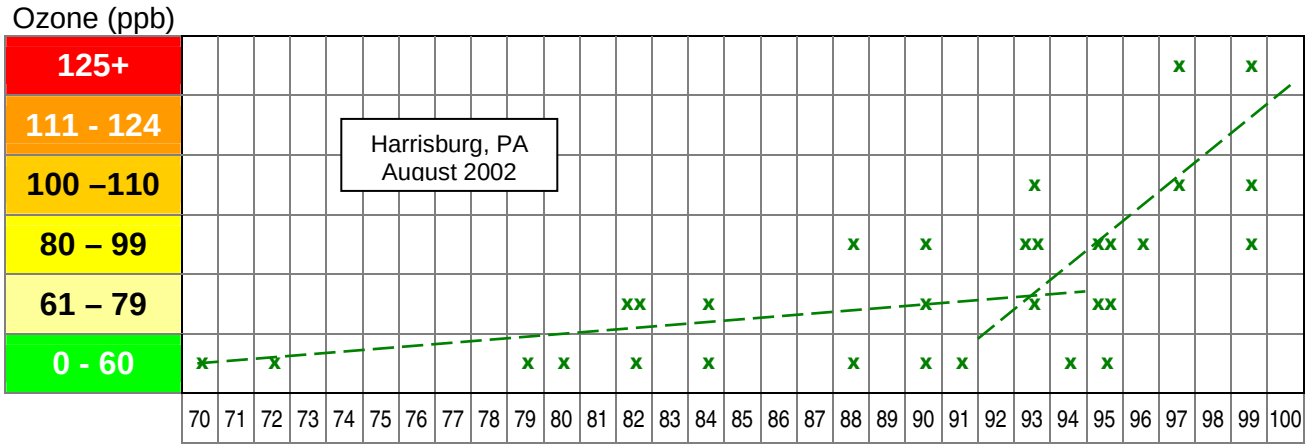
    a. Describe the scatter of data in the graph of ozone versus temperature. Is there any trend in the data? If so, explain how the two variables appear to be related.
    There is a general increase in ozone levels as temperature rises (a positive correlation between ozone and temperature). Below about 90^{o}F, the increases are moderate, Above 90^{o}F, ozone levels appear to rise more rapidly with increasing temperature. However, there is a fair amount of scatter in the data; so there must be other factors at work in addition to temperature.

    b. Answer the same question for the graph of ozone versus wind speed.
    Ozone levels tend to diminish with increases in wind speed (a negative correlation). As in the preceding graph, there is a substantial amount of scatter in the data plot.

    c. What possible explanations are there for any observed relationships?
    Both temperature and wind speed appear to influence ozone levels. The first graph supports the finding that higher air temperatures contribute to ozone formation at concentrations considered unhealthy or dangerous. The second graph indicates that Increasing wind speed has the opposite effect. It makes sense that greater air circulation would help to drive away pollutants like ozone and other chemicals present in smog.

ANSWER KEY

1-hour Average Peak Ozone Concentration vs. Maximum Temperature



1-hour Average Peak Ozone Concentration vs. Mean Wind Speed