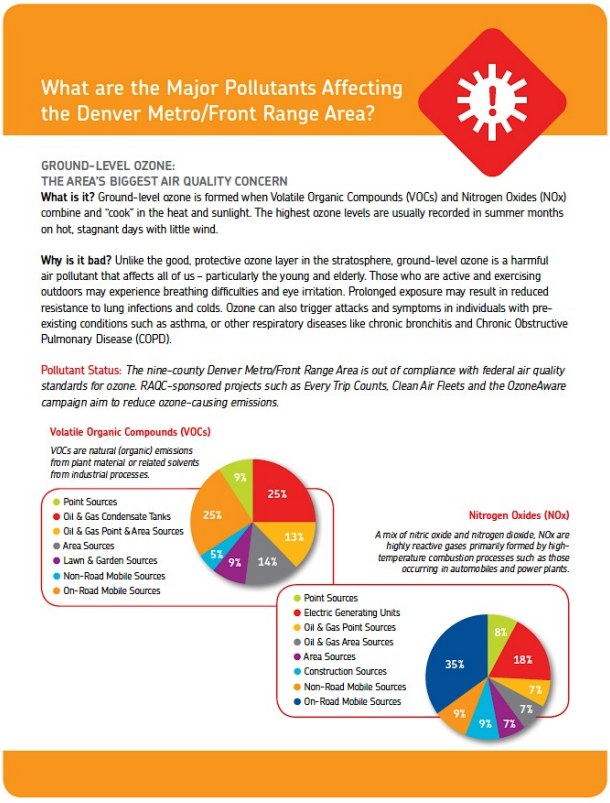
Name: _____ Date: _____

1.2 Oh No, O_3zone: "Good Up High, Bad Nearby!" – Student Investigation Guide

Background:



The protective ozone layer, located about 25 km above Earth's surface in the stratosphere, shields our planet and its living things from the Sun's harmful UV radiation.

Ozone studied by the joint FRAPPÉ and DISCOVER-AQ campaign was located in the troposphere, the layer below the stratosphere, which extends from the ground up to approximately 10km above the Earth's surface. Ground level ozone is a "secondary pollutant" meaning it is not directly emitted into the air but is formed from other pollutants, mainly volatile organic compounds (VOCs) and nitrogen oxides (NOx), that are emitted into the air.

The main factor that causes the formation of ground-level ozone pollution is sunlight. Ozone typically peaks during the summer months when sunlight is more intense and daylight is longer. Also, weather patterns during the summer are more stable with sunny days, clear skies, and high temperatures all of which favor the production of ground-level ozone pollution.

At Earth's surface, ozone is a toxic and damaging pollutant to living things. Ground level ozone affects plants, including crops, by damaging their leaves, which then affects photosynthesis and plant growth. Affected plants are at an increased risk from further stress and damage caused by insects, other pollutants, competing species, and harm from severe weather. These negative impacts can then affect ecosystems by decreasing their biodiversity and habitat quality. In humans, breathing ozone decreases lung function and irritates the linings of the lungs that can then worsen existing respiratory diseases such as asthma and bronchitis. Repeated exposure to breathing ozone may permanently scar lung tissue. Ozone is an oxidant and breathing it has been described as a "sunburn" in your lungs.

Image: Regional Air Quality Council/OzoneAware.org
Source: https://www.eol.ucar.edu/frappe/eo

Day 1Engage

Video: "Studying Ground Level Ozone in the Colorado Front Range"

Watch this fun video that explains the causes, effects, and the science behind ground-level ozone pollution:
https://www.eol.ucar.edu//eo

O_3 Graphic Organizer: "Good Up High, Bad Nearby" Ozone in the Atmosphere

Explore ozone by comparing and contrasting the "good" protective stratospheric ozone layer in relation to "bad" tropospheric ground-level ozone air pollution.
Study the image below. What key information, patterns, and factors, etc. describe ozone's role in the atmosphere?

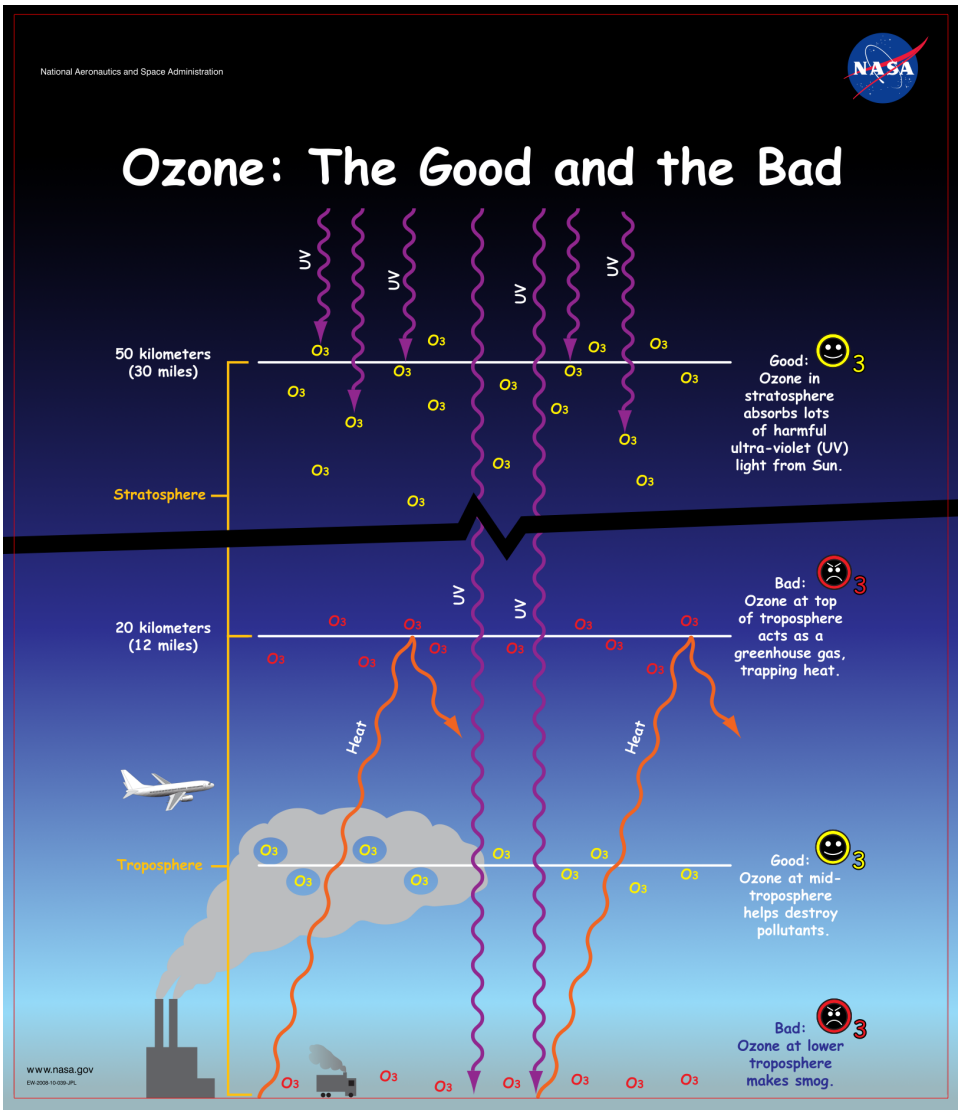


Image source: http://nasawavelength.org/resource/nw-000-000-002-915

Explore
Ozone Formation Introduction:
The basic "recipe" for ground-level ozone is:

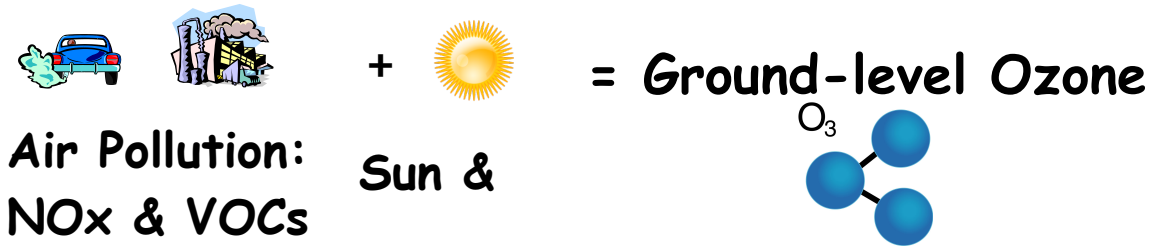


Image adapted from EPA

Ground-level ozone is formed when nitrogen oxides (NOx) and volatile organic compounds (VOCs) mix in the air and sunlight "cooks" (chemically combines) these compounds together to make ozone. The highest ground-level ozone levels are usually recorded during the summer months on sunny, hot days with little wind. However, passing weather fronts that are often accompanied by increased cloudiness and stronger winds can reduce the formation of ozone and "push" polluted air out of the area.

Ozone is not directly emitted into the air but is a "secondary pollutant" formed from other air pollutants. In order to understand ground-level ozone, scientists not only measure ozone but also the compounds that contribute to its formation. The ozone-forming compounds, NOx and VOCs (ozone precursors), mainly come from fuel combustion sources (e.g. fossil-fueled vehicles, equipment, power plants, industrial & agricultural processes, etc.).

Kinesthetic Ozone Formation
Students will simulate the formation of ground-level ozone in order to gain knowledge of the main air quality concern in the Northern Front Range. They will understand how peoples everyday actions and daily weather conditions interact to affect the area's air quality.

Materials & Equipment:
- Outdoor area or indoor room with ample space with the following locations designated:
  - Factory
  - Roadways
  - Lawns
- Colored sharpies – orange, red, brown, black, green, blue
- Name tags or Post-It Notes (or other objects to identify groups)

Kinesthetic Ozone Formation Scenario 1:
In an outdoor or indoor open space, have the students line up and count off one through six. Post and review the following group assignments with the class. Next, hand out relevant materials to each group and instruct students to create and place labels for their group accordingly:

- Group 1: Orange Sharpie & labels. One student is labeled "Sun" and remaining students are labeled "sunlight" in the group, placed on their upper chest
- Group 2: Red Sharpie & labels. One "Vehicle" label for each student in the group, placed on their right shoulder
- Group 3: Brown Sharpie & labels. One "Vehicle Exhaust-NOx" label for each student in the group, placed on their back
- Group 4: Black Sharpie & labels. One "Factory Exhaust-VOC" label for each student in the group, placed on their back
- Group 5: Green Sharpie & labels. One "Lawn Mower" label for each student in the group, placed on their left shoulder
- Group 6: Blue Sharpie & labels. One "Lawn Mower Exhaust-NOx" label for each student in the group, placed on their back

The teacher reads the following scenarios aloud. Each group responds according to the actions and instructions read:

1. "The day begins as the sun rises. The weather today is sunny and hot!"

2. "In the morning, people drive to work and school."

3. "The work day has started at the factory. Exhaust starts flowing out of the smokestacks into the air."

4. "It's late morning, people start to mow their lawns."

5. "People are continuing to drive, work, and mow. It is now midday and the Sun is at its highest point in the sky."

6. "People now take lunch breaks at midday from their activities."

7. "Even though the vehicles and lawn mowers are not driving or mowing, their exhaust pollution is still moving through the air. Sunlight, which is most intense at midday, begins to chemically transform the exhaust pollutants into ground-level ozone."

8. Group Discussion:
   Using one 3-student group that has been combined into an "ozone" molecule, demonstrate to the class that exhaust (emission) pollutants (NOx and VOCs) mix together in the air and that sunlight drives the chemical reaction that forms them into toxic ground-level ozone. Remind students that when ground-level ozone pollution levels exceed healthy levels in the air all living things that breathe and need good air quality to survive are affected, including humans!

9. Students return to their original groups and if their label was changed they are to replace it with their original label.

Kinesthetic Ozone Formation Scenario 2:
In the next scenario, explain that the situation is changed because people are choosing to use alternative transportation and the weather conditions are more windy and cloudy.

What do you predict would happen to the air quality and level of ground-level ozone if the amount of NOx and VOCs emitted into the air is reduced?

If sunny, clear, hot days contribute to the formation of ground-level ozone what do you predict cloudy and windy weather conditions would do to ground-level ozone formation?

- Group 1: Orange Sharpie & labels. One "Sun" label and "Sunlight" labels for remaining students in the group, placed on their upper chest
- Group 2: Red Sharpie & labels. One "Vehicle" label for each student in the group, placed on their right shoulder (select 1-2 students from Group 2 to be reassigned to group 5 below)
- Group 3: Brown Sharpie & labels. One "Vehicle Exhaust-NOx" label for each student in the group, placed on their back (select 1-2 students from Group 3 to be reassigned to group 6 below)
- Group 4: Black Sharpie & labels. One "Factory Exhaust-VOC" label for each student in the group, placed on their back
- Group 5: Green Sharpie & labels. Alternative transportation - each student in the group chooses either "Bus", "Train", "Tram", "Bike", "Walk" or other form of alternative transportation label, placed on their back (they are not paired with an "exhaust" pollutant since they are reducing total emissions by reducing the number of personal vehicles used).
- Group 6: Blue Sharpie & labels. One "Wind" or "Cloud" label for each student in the group, placed on their back

1. "The day begins as the sun rises. The weather today is partly cloudy and breezy."

2. "In the morning, people drive to work and school."
3. "Some people have chosen to take public transportation or other alternative ways to get to school and work."

4. "The work day has started at the factory. Exhaust starts flowing out of the smokestacks into the air."

5. "People are continuing to their driving, transportation and work. It is now midday and the Sun is at its highest point in the sky."

6. "People now take lunch breaks at midday from their activities."

7. "Even though the vehicles are not driving and alternative transportation has decreased exhaust, pollution is still moving through the air. However, increased clouds and wind help prevent the formation of some ozone by blocking sunlight and blowing air pollution out of the area."

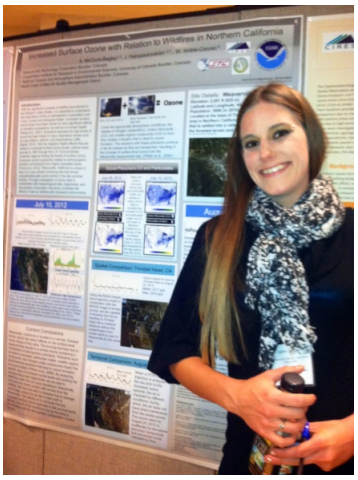
8. Group Discussion:
   - Compare and contrast the amount of ground-level ozone pollution formed in the first and second scenarios.
   - Which scenario formed the greater amount of ozone pollution? Which factors contributed to increased ground-level ozone levels and which factors resulted in decreased ozone levels?"
   - Why was the total amount of ground-level ozone formed in the second scenario less than the amount of ozone formed in the first scenario?
   - One suggestion to help reduce ozone-forming pollution is to postpone mowing lawns and using other gas-powered lawn equipment until early evening. How did the absence of lawn mower exhausts affect the formation of ozone?
   - What are the three "ingredients" for creating ground-level ozone pollution?

9. Clean Up: students are to clean up activity materials and return to their classroom seats.

Activity adapted from OzoneAware.org resources provided for the "Know Your AQ" Workshop.

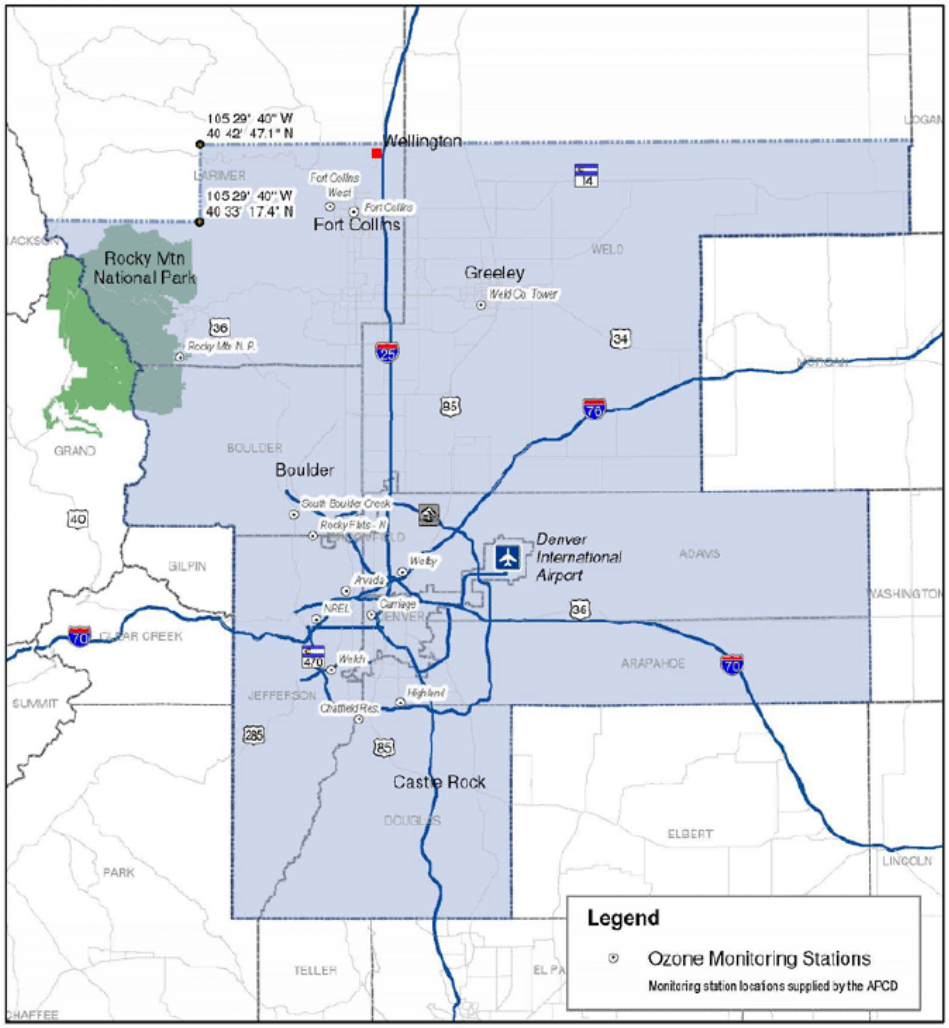
Day 2
Explain (30 min.) *Students construct their understanding of conditions that affect ground level ozone formation and transport and develop evidence-based explanations using research data.*

Scientist Snapshot:
Meet the scientists who conduct groundbreaking research to understand and find solutions to improve air quality for people, places, and all living things!



Audra McClure-Begley, CIRES/NOAA
Atmospheric Scientist
Audra conducts atmospheric research with CIRES at the University of Colorado-Boulder and NOAA-Global Monitoring Division. Audra was born in Boulder, Colorado and raised on a small farm outside of Columbia, Missouri. She began working for NOAA-Global Monitoring Division's Ozone and Water Vapor group after receiving her Bachelors degree from the University of Colorado-Boulder. She enjoys hiking, horseback riding, rock-climbing, camping, and being outdoors, which makes the hikes to mountain monitoring stations, such as Niwot Ridge, a day of doing what she loves most. An avid skydiver with little to no fear of heights, the 300 meter climbs to the top of the Boulder Atmospheric Observatory (BAO) in Erie, CO to monitor the ozone are no big challenge. Her work and research is driven by the desire to improve public understanding of air quality and ozone production in relation to the effects ozone has on ecosystems. She shares her life with her Service Dog, Rhea, and a variety of other pets.

O_3nce Upon a Time – Telling the Story About the Highs and Lows of Ozone
Introduction:
Students will analyze ground level ozone from the 2014 FRAPPÉ and DISCOVER-AQ air quality campaign. In this activity, students will gain a basic understanding of the complex interactions among factors that form ground-level ozone pollution. Review the map of the Front Range's non-attainment area, which regularly exceeds safe ground-level ozone values.



Denver-Boulder-Greeley-Fort Collins, Colorado
Eight-Hour Ozone Control Area

DRCOG
Denver Regional Council of Governments
Metro Vision Resource Center
June 2004

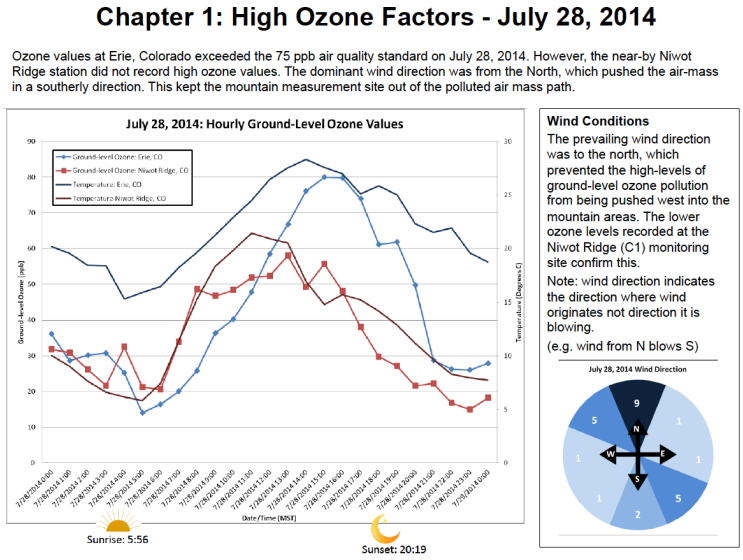
O_3nce Upon a Time – Telling the Story About the Highs and Lows of Ozone

Ozone Analysis Activity:

Following a story-telling format, students will analyze three different ground-level ozone scenarios, which incorporate data recorded at the Boulder Atmospheric Observatory (BAO) and Niwot Ridge Monitoring Station as part of the from the joint 2014 FRAPPÉ and DISCOVER-AQ air quality campaign. Through this three-part activity, students will gain an understanding of the correlation between sunlight, temperature, weather conditions and the formation of toxic ground-level ozone pollution. The accompanying "Once Upon a Time" activity packet has all the details!

Chapter 1: High Ozone Factors

On the same day, why do some nearby areas experience high levels of ground-level ozone air pollutions and some don't?

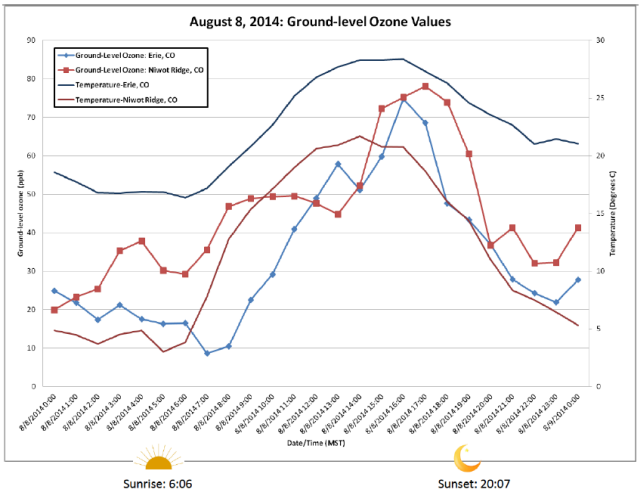


Chapter 2: Ozone and Upslope Wind

How can areas that do not have the precursor primary pollutants that form ozone still experience high levels of ground-level ozone?

Chapter 2: Ozone and Upslope Wind - August 8, 2014

Ozone values at both stations exceeded the 75 ppb level of ozone exceedance, but why? The Niwot Ridge station peaks in ozone values about one hour after the peak of ozone at Erie, Colorado. This can be attributed to the time it takes for the polluted air mass to be transported up the mountain slope to the high elevation monitoring site.
High ozone episodes in the high elevation Rocky Mountains have added concern for alpine ecosystem functioning, including forest health and biodiversity in the mountains.

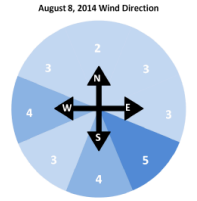


Wind Conditions

In contrast, the direction of the wind pushed the ground-level ozone west into the mountains. The higher ozone levels recorded at the Niwot Ridge (C1) monitoring site confirm this.

Note: wind direction indicates the direction where wind originates not direction it is blowing.

(e.g. wind from SE blows NW)

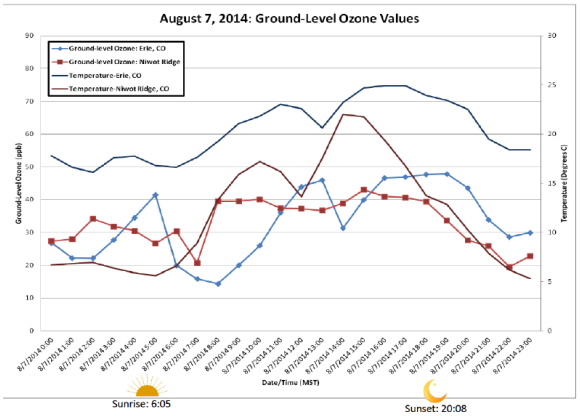


Chapter 3: Ozone and Clouds

What affect does the Sun really have on the formation of ground-level ozone pollution?

Chapter 3: Ozone & Clouds - August 7, 2014

The basic formula for ozone production is NOx + VOC + Sunlight = Ozone. Clouds prevent UV solar radiation from reaching ozone-forming molecules that would react in sunlight to form ground-level ozone. August 7th had higher cloud coverage and lower ozone values compared to August 8th, which had clear skis, warmer temperatures, and higher ozone values.



Compare & Contrast Ozone & Temperature Data:

1. Maximum ozone value at BAO: _____ppb
2. Maximum ozone value at Niwot Ridge: _____ppb
3. Maximum temperature at BAO: _____C
4. Maximum temperature at Niwot Ridge: _____C
5. Did the BAO (Erie, CO) air monitoring site record unsafe ozone values (above 75 ppb)?

   Yes No
6. Did the Niwot Ridge air monitoring site record unsafe ozone values (above 75 ppb)?

   Yes No

Elaborate (15 min.) *Students deepen and expand their understanding of how individuals can access information on air quality conditions and actions that they can take to reduce air pollution.*

Air Quality Index for Ozone

(based on 8-hr average concentrations)

Index Values (Conc. Range)	Air Quality Descriptors	Cautionary Statements for Ozone
0 – 50 (0-59 ppb)	Good	**No health impacts are expected when air quality is in this range.**
51 – 100 (60-75 ppb)	Moderate	**Unusually sensitive people should consider limiting prolonged outdoor exertion**
101 – 150 (76-95 ppb)	Unhealthy for Sensitive Groups	**Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion**
151 – 200 (96-115 ppb)	Unhealthy	**Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children should limit prolonged outdoor exertion.**
201 – 300 (116-374 ppb)	Very Unhealthy	**Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.**

Source: EPA.gov

Ozone Air Quality Index and Ozone Action Alerts:
Sunny, hot, low wind days can help turn emissions from vehicles, power plants, and other human-generated sources of air pollution into unhealthy ground-level ozone. In the summertime, the Regional Air Quality Council calls Ozone Action Alert days when ozone levels are high in order to encourage people to reduce their behaviors and actions that contribute to the formation of ground-level ozone pollution.

How does ground level ozone pollution affect my health?
At ground level, ozone is a toxic pollutant that can cause lung irritation and cause health concerns, especially for children, the elderly, active, and those suffering from respiratory ailments, including asthma. Click the link to learn about the specific health concerns and who is most at risk from ground level ozone pollution:

- Health Effects of Ozone
  http://www.epa.gov/groundlevelozone/health.html

How can I find out current and reliable air quality current conditions & forecasts in Colorado and other locations in the US?
Students can get real-time air quality conditions and forecasts on their computer, tablet, and smart phones. Share and explore this web link to see current air quality conditions and forecasts throughout the US:

- AirNow.gov (click on the map to select a region and view its air quality details):
  http://www.airnow.gov/

What can I do to help reduce ozone and other air pollution?
Explain that there are many things being done to raise awareness and action to reduce air pollution that causes ground-level ozone. One thing students and their families can do is participate in the OzoneAware.org program. This program educates and encourages people to reduce pollution on days when the weather conditions make ozone formation more likely.

Project these websites, or have students explore them independently, and navigate through the websites. As a class, share numerous simple changes in choices and actions that students and their families can take to help reduce ozone-forming pollution from the OzoneAware and EPA websites:

- OzoneAware.org
  http://ozoneaware.org
- Ways to Reduce Air Pollution
  http://www.epa.gov/air/caa/peg/reduce.html

Evaluate
Ground-level Ozone Quick Quiz:
Students complete a quick, informal summative assessment exit ticket or clicker question to evaluate their basic understanding of how ground-level ozone is formed.

What are the two main air pollutants that combine to form harmful ground-level ozone pollution? (circle two choices):
○ Nitrogen Oxides (NOx)
○ Carbon Dioxide (CO_2)
○ Volatile Organic Compounds (VOCs)
○ Carbon Monoxide (CO)

Which statement best describes how weather conditions affect the formation of ground-level ozone (circle one choice)?
○ Cloudy, cool temperatures, and high winds favor ozone formation
○ Sunny, high temperatures, and low winds favor ozone formation
○ All weather conditions favor ozone formation
○ No weather conditions favor ozone formation

Ground-level ozone affects human health by damaging (circle one choice):
○ the cardiovascular system (heart and blood vessels)
○ the digestive system (stomach and intestines)
○ the nervous system (brain and nerves)
○ the respiratory system (lungs and air ways)