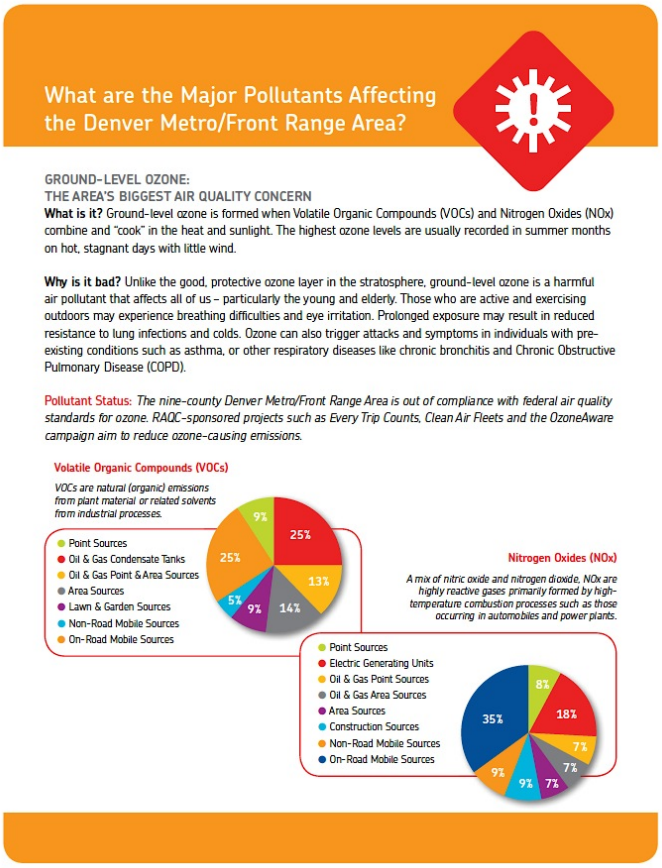
1.2 Oh No, O_3zone: "Good Up High, Bad Nearby!" – Teacher Guide

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 getting a "sunburn" in your lungs.

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

Lesson Goals, Objectives, Vocabulary & Standards:

- Essential Question: What is ground-level ozone pollution, where does it come from, and how does it affect the air quality of Colorado's Front Range?

- Learning Objective/s:
  - Identify the two main locations of ozone in the atmosphere.
  - Explain the chemistry of ground-level ozone pollution formation.
  - Analyze data from an upslope ground-level ozone air pollution event.
  - Discuss how weather conditions, topography, and time of day and year contribute to an upslope ground-level ozone pollution event.

- Academic Vocabulary:
  1. Atmosphere
  2. Nitrogen Oxide
  3. Ozone Layer
  4. Ground-level Ozone
  5. Ozone Alert
  6. Stratosphere/stratospheric
  7. Topography
  8. Troposphere/tropospheric
  9. Upslope
  10. Volatile Organic Compounds
  11. Weather

- Standards:

NGSS Disciplinary Core Ideas:
MS-PS1-2
MS-LS2-5

NGSS Science and Engineering Practices:
Asking Questions and Defining Problems
Developing and Using Models
Analyzing and Interpreting Data
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information

NGSS Crosscutting Concepts:
Patterns
Cause and Effect
Scale, Proportion, and Quantity
Systems and System Models
Stability and Change

Colorado Academic Standards:
6th grade Physical Science 1.2
6th grade Life Science 2.1
21st Century Skills and Readiness Competencies in Science:
- Critical Thinking and Reasoning
- Information Literacy
- Collaboration

Lesson Preparation:

- Time: 100 min. - 2 class periods / 1 block

- Materials & Equipment:
  - Technical requirements:
    - Classroom computer with projector & screen or computer lab with Internet access
    - Printer and copier to make student handouts

  - Activity materials & equipment (per student or group):
    - Color Sharpies
    - Name tag stickers or Post-It Notes
    - Outdoor open space or large open indoor space

  - Student handouts (per student):
    - "Oh No, O_3zone!: "Good Up High, Bad Nearby" Student Investigation Guide
    - "O_3nce Upon a Time" Ozone Analysis Activity
    - "Ground-level Ozone Quick Quiz" informal summative assessment

  - Preparation of additional lesson elements:
    - Bookmark the "Studying Ground Level Ozone in the Colorado Front Range" video:
      https://www.eol.ucar.edu//eo
    - Bookmark and/or print "Ozone: Good Up High, Bad Nearby" online poster:
      http://nasawavelength.org/resource/nw-000-000-002-915
    - Bookmark the Niwot Ridge LTER website and live tundra cam:
      http://niwot.colorado.edu
      http://instaar.colorado.edu/tundracam/index.php
    - Bookmark the Boulder Atmospheric Observatory (BAO) site and live tower web cam webpages:
      http://www.esrl.noaa.gov/psd/technology/bao/site/
      http://www.esrl.noaa.gov/psd/technology/bao/webcam/

  - Build knowledge and address misconceptions of lesson content:
    - Embed instruction of academic vocabulary within lesson activities
    - Misconception: Sunny, clear, blue skies represent healthy air quality.

Day 1

Engage (15 min.) *Interest in ground-level ozone is generated and students' current understanding of ozone's roles in the atmosphere is addressed.*

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?

Hand each student a copy of the "1.2 Oh No, O_3zone!" investigation packet. Review the "Ozone: The Good and the Bad" image with students. Ask: What key information, patterns, and factors, etc. describe ozone's role in the atmosphere?

Answers: ozone in the stratosphere is beneficial in absorbing the Sun's harmful UV light, ozone in the lower (ground-level) troposphere is a pollutant but mid-troposphere ozone helps destroy pollutants, and ozone in the upper troposphere acts a greenhouse gas (like carbon dioxide and methane) and traps heat in the atmosphere.

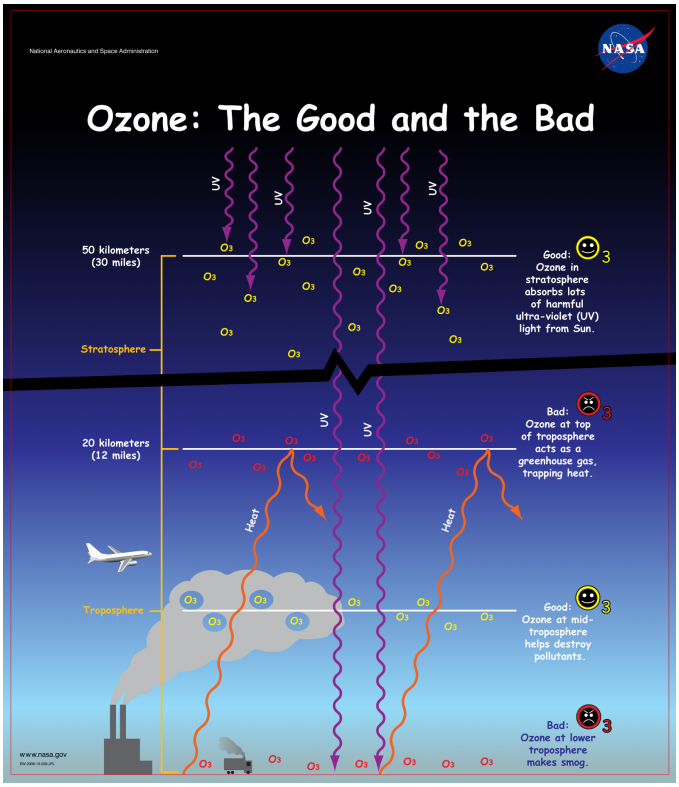


Image source: http://nasawavelength.org/resource/nw-000-000-002-915

Explore (35 min.) *Students participate in kinesthetic activities to explore the process ground-level ozone formation and factors that affect its levels in the atmosphere.*

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

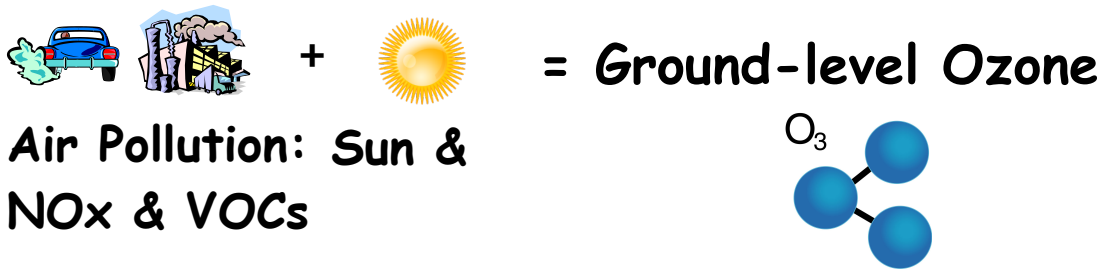


Image adapted from EPA

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 read:

1. Say: "The day begins as the sun rises. The weather today is sunny and hot!"
Instruct: Tell one student from group 1 "sunlight" to represent dawn and enter the space. As morning progresses, have additional "sunlight" enter as each of the following scenarios are read aloud.

2. Say: "In the morning, people drive to work and school."
Instruct: Tell group 2 to start moving and to lock arms with a person from group 3, "exhaust pollution" with them. As the "vehicles" drive around, the "exhaust pollutants" follow the vehicle's path.

3. Say: "The work day has started at the factory. Exhaust starts flowing out of the smokestacks into the air."
Instruct: Tell Group 4 "factory exhaust" to start moving around the space from the "factories" location in the room.

4. Say: "It's late morning, people start to mow their lawns."
Instruct: Tell Group 5 "lawn mowers" and group 6 "lawn mower exhaust" to lock arms and move around the "lawn" area of the room.

5. Say: "People are continuing to drive, work, and mow. It is now midday and the Sun is at its highest point in the sky."
Instruct: Ask all "sunlight" students to be moving through the space at this point in time.

6. Say: "People now take lunch breaks at midday from their activities."
Instruct: Tell the "exhaust" pollutants to unlock arms from their "vehicle" or "lawn mower"

sources and to mix with "factory exhaust" in the "air". Ask the driving and lawn-mowing students to sit together in a group for their lunch break, and observe what happens next.

7. Say: 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. Instruct: the "sunlight" students to take one "vehicle exhaust", one "lawn mower exhaust", and one "factory exhaust" student and lock their arms together a 3-student long chain, which represents a molecule of ozone. After the "sunlight" forms an ozone molecule, tell them to replace the "vehicle exhaust", "lawn mower exhaust", and "factory exhaust" labels with a single "Ground-level Ozone" label placed on the middle student's back. Continue this process until all the "sunlight" has combined all "exhaust" pollutants into ground-level "ozone" molecules. If there are not enough students available to create a complete 3-student "ozone" molecule chain, tell the remaining "exhaust" pollutants to remain in the air as is.

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. Direct students to 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.
Ask: 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? Air quality would improve and ground-level ozone levels would be lower.
Ask: 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? Since sunlight "drives" ozone formation, cloud cover reduces the amount of sunlight available to form ground-level ozone. Windy weather can blow ozone forming pollutants and ozone away from an area thus reducing high ground-level ozone levels.

- 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

Reassign the “lawn mower” and “lawn mower exhaust” groups, as follows:

- 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. Say: “The day begins as the sun rises. The weather today is partly cloudy and breezy.”
Instruct: Tell one student from group 1 “sunlight” to represent dawn and enter the space. As morning progresses, have additional “sunlight” enter as each of the following scenarios are read aloud.

2. Say: “In the morning, people drive to work and school.”
Instruct: Tell group 2 to start moving and to lock arms with a person from group 3, “exhaust pollution” with them. As the “vehicles” drive around, the “exhaust pollutants” follow the vehicle’s path.

3.Say: “Some people have chosen to take public transportation or other alternative ways to get to school and work.”
Instruct: Tell group 7 to move to their workplace or school (they are not paired with an “exhaust” pollutant since they are reducing total emissions by reducing the number of personal vehicles used).

4. Say: “The work day has started at the factory. Exhaust starts flowing out of the smokestacks into the air.”
Instruct: Tell Group 4 “factory exhaust” to start moving around the space from the “factories” location in the room.

6. Say: “People are continuing to their driving, transportation and work. It is now midday and the Sun is at its highest point in the sky.”
Instruct: Ask all “sunlight” students to be moving through the space at this point in time.

7. Say: “People now take lunch breaks at midday from their activities.”
Instruct: Tell the “exhaust” pollutants to unlock arms from their “vehicle” and to mix with “factory exhaust” in the “air”. Ask the driving and alternative transportation students to sit together in a group for their lunch break, and observe what happens next.

8. Say: “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."
Direct the following actions:

- "Sunlight" students create "ozone" molecules by combining three total "vehicle exhaust" and "factory exhaust" students together by locking their elbows.
- After the "sunlight" forms an ozone molecule, tell them to replace the "vehicle exhaust" and "factory exhaust" labels with a single "Ozone" label placed on the middle student's back.
- Now the weather has changed, tell the "cloud" and "wind" students to enter.
- The "Cloud" students can tap "sunlight" students on the shoulder to "block" the "sunlight" from forming the "Ozone" molecules (if a "sunlight" student is tapped, they are to join the group of seated students).
- The "wind" students can tap the "exhaust" pollutants on the shoulder to "blow" them out of the area before the remaining "sunlight" students can form the pollutants into ozone (if an "exhaust" student is tapped, they are to join the group of seated students).
- The "wind" can also tap the "ozone" molecules on the shoulder to "clear" the air of ground-level ozone pollution (if an "ozone" group is tapped, they are to join the group of seated students).
- Continue this process until one of the outcomes occur:
  - "Sunlight" has combined all "exhaust" pollutants into ground-level "ozone" molecules
  - "Clouds" have blocked all the "sunlight"
  - "Wind" has cleared all pollutants, including ozone.

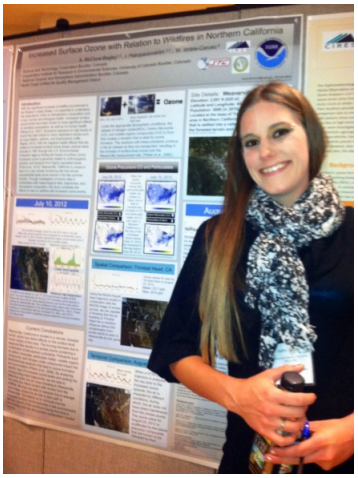
9. Group Discussion: "Now, we're going to compare and contrast the amount of ground-level ozone pollution formed in the first and second scenarios. Ask: Which scenario formed the greater amount of ozone pollution? Which factors contributed to increased ground-level ozone levels and which factors resulted in decreased ozone levels?"
Ask: "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?" Less vehicles and more alternative transportation used, clouds prevented ozone from being formed by blocking the sun, and wind cleared away air pollutants (note: though the air pollutants were blown away they did not "disappear" but rather were moved elsewhere through the atmosphere, which still adds to overall air pollution levels). Lawn mowing did not occur.
Say: One suggestion to help reduce ozone-forming pollution is to postpone mowing lawns and using other gas-powered lawn equipment until early evening. Ask: How did the absence of lawn mower exhausts affect the formation of ozone? Not mowing earlier in the day decreased the amount of ozone-forming pollutants in the air.
Ask: "What are the three "ingredients" for creating ground-level ozone pollution?" Nitrogen oxides (NOx) and volatile organic compounds (VOCs) and sunlight on sunny, hot days with little or no wind and clouds.

10. Direct students 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!

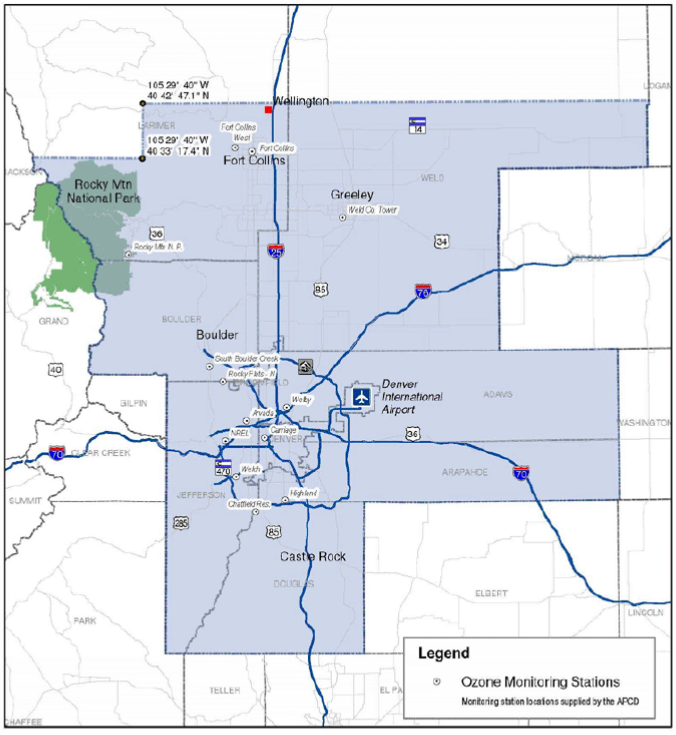


Audra McClure-Begley, CIRES/NOAA
Atmospheric Scientist
Audra conducts atmospheric research with CIRES at the University of Colorado-Boulder and NOAA-Global Monitoring Division. Audra was born in Boulder, Colorado and raised on a small farm outside of Columbia, Missouri. She began working for NOAA-Global 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
June 2004

The highest levels of ground-level ozone pollution are usually recorded in the summer months on hot, stagnant days with little wind and plenty of sunshine. Ground-level ozone is measured once per hour at multiple locations through out the Denver metro and Front Range area. It is recorded as average concentrations measured every 8-hours. Ground-level ozone concentrations are recorded throughout the year to determine whether a geographic region is in compliance with the federal EPA 8-hour standard for the pollutant, which is 75 parts per billion (ppb). Currently, the Denver Metro and Front Range area is out of compliance with federal air quality standards for ground-level ozone levels.

http://www.epa.gov/airquality/ozonepollution/actions.html#nov2014

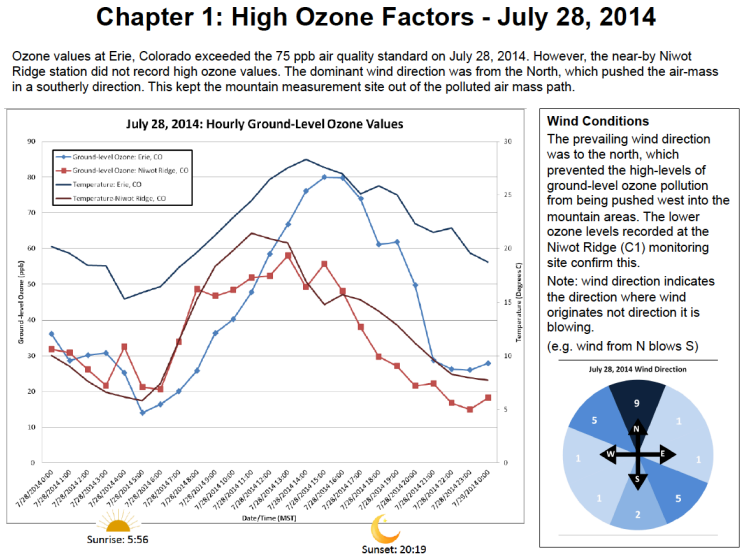
O_3nce Upon a Time – Telling the Story About the Highs and Lows of Ozone

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?

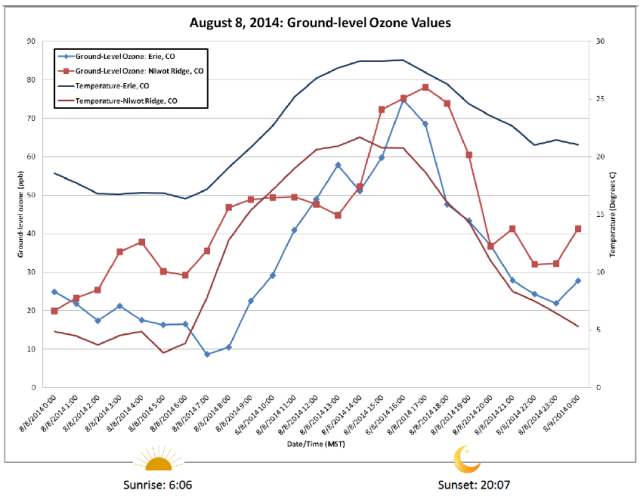


Chapter 2: Ozone and Upslope Wind

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.

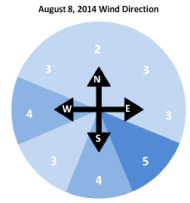


Wind Conditions

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)

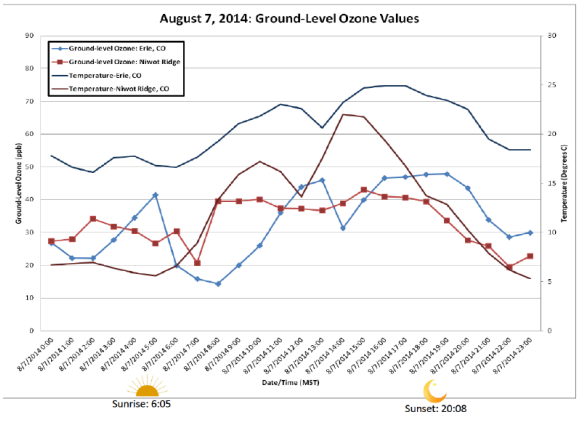


Chapter 3: Ozone and Clouds

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 (5 min.) *Students and teachers have opportunities to assess students' basic understanding of ground-level ozone formation.*

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)

Additional Resources

- Differentiation & Extensions
- US EPA Interactive Ozone Maps: http://www.epa.gov/airquality/ozonepollution/maps.html

- References & background information:
  - Good Up High Bad Nearby: What is Ozone?
  - http://www.airnow.gov/index.cfm?action=gooduphigh.index
  - AirNow.gov Colorado AQI Forecast & Current Conditions http://www.airnow.gov/index.cfm?action=airnow.local_state&stateid=6&mapcenter=0&tabs=0
  - CDPHE Draft 2014 CO Ozone 4th highest 8hr-Ozone Values: http://www.colorado.gov/airquality/html_resources/ozone_summary_table.pdf
  - UCAR Center for Science Education Air Quality Teaching Box http://scied.ucar.edu/air-quality

- Download lesson files (pdf, .zip):
  - "O_3nce Upon a Time" Ozone Analysis Activity pdf