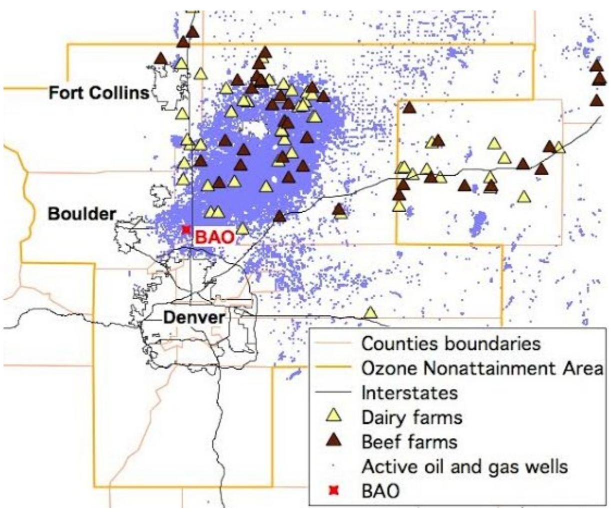
1.4 Carbon Gases CSI: Mobile Lab, Methane & More – Teacher Guide

Background:

A few years ago, routine atmospheric measurements at the Boulder Atmospheric Observatory (BAO) turned up surprisingly high levels of chemical substances. CIRES researcher Gabrielle Pétron used a mobile laboratory to search for sources.

Pétron, who works at the NOAA Earth System Research Laboratory (ESRL), outfitted a passenger car and later a van with sensitive instruments designed to measure real-time methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), and ozone (O_3), and to collect air samples for later chemical analysis of several VOCs (volatile organic compounds).



(Source: NOAA)

She and her colleagues drove along public roads in northeast Colorado, targeting areas downwind of many possible sources: landfills, feedlots, and oil and gas operations. Onboard instruments helped them identify plumes of air rich in emissions. After thousands of readings and analysis of dozens of air samples on NOAA's ultra-sensitive instruments, her team identified a key source for methane and other chemical pollutants.

Since the original data were collected in 2008, Pétron and her colleagues have continued their fieldwork, using increasingly sophisticated instruments for airborne and ground-based measurements.

Adapted from:
http://cires.colorado.edu/science/spheres/

(Images: CIRES)

Lesson Goals, Objectives, Vocabulary & Standards:

- Essential Question: What are the main sources of carbon gases in the Northern Front Range of Colorado and what are their impacts on air quality?

- Learning Objectives:
    - Identify natural and anthropogenic sources of carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4) emissions.
    - Connect observed levels of carbon gases from the NOAA Mobile Laboratory drives to some of these sources.
    - Describe the potential impacts of carbon gases on air quality (including human health and the environment).
    - Design solutions for reducing anthropogenic carbon gas emissions

- Academic Vocabulary:
    - Air quality (human health & environmental)
    - Ambient air
    - Analyze
    - Anthropogenic (human) activities
    - Carbon gas
    - Carbon dioxide (CO_2)
    - Carbon monoxide (CO)
    - Concentrated animal feeding operation (CAFO) or feedlot
    - Emit/Emissions
    - Landfill
    - Methane (CH_4)
    - Oil & Gas well (O&G)
    - Parts per million (ppm)
    - Parts per billion (ppb)
    - Source (point-source vs. non-point source)

- Standards:

NGSS Disciplinary Core Ideas:
MS-LS2-3
MS-PS1-1
MS-ESS3-5

NGSS Science and Engineering Practices:
Asking Questions and Defining Problems
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
Energy and Matter
Stability and Change

Colorado Academic Standards:
6th grade Physical Science 1.2
6th grade Life Science 2.2
6th grade Earth Science 3.3

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 period
- Materials & Equipment:
    - Technical requirements:
        - Classroom computer with projector & screen or computer lab with Internet access
    - Activity materials & equipment (per student since individual impacts on air quality differ but are cumulative):
        - Butcher paper/poster board
        - Color markers and colored pencils
        - "1.4 Mobile Lab" investigation student guide (one per student)
        - One full-size copy of each file in the "Maps and Graphs" folder (one copy of folder per group)
        - Carbon gases "fast facts" (one "fast fact packet/link per group based on each group's assigned carbon gas):
          CO: http://www.epa.gov/airquality/carbonmonoxide/
          CO_2: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html
          CH_4: http://epa.gov/climatechange/ghgemissions/gases/ch4.html
    - Preparation for lesson elements:
        - Bookmark the "Fracking's Methane Trail" NPR radio interview: http://www.npr.org/2012/05/17/151545578/frackings-methane-trail-a-detective-story
        - Bookmark and/or print carbon gases "fast facts" resource information:
          CO: http://www.epa.gov/airquality/carbonmonoxide/
          CO_2: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html
          CH_4: http://epa.gov/climatechange/ghgemissions/gases/ch4.html
        - Divide the class into six student teams (two teams will research CO, two teams will research CO_2, and two teams will research CH_4)
    - Build knowledge and address misconceptions of lesson content:
        - Embed instruction of academic vocabulary within lesson activities
        - Students should understand how to read and interpret X-Y data plots
        - Misconception: "The only greenhouse gas emitted by human activities is carbon dioxide from burning fossil fuels." This statement is not accurate as several types of human activities lead to significant emissions of greenhouse gases. In addition to burning fossil fuels, burning wood for cooking and heating also releases carbon dioxide (CO_2) Also, when cement is made from ground up limestone, the hardening process releases CO_2. Agriculture, including growing rice and raising livestock, leads to the release of increased amounts of methane. Methane is another greenhouse gas that is less abundant in the atmosphere but is 10 times more effective in trapping heat than CO_2.

Day 1
In this activity, you will be introduced to the NOAA Mobile Laboratory and its air monitoring research drives, which contributed to the FRAPPÉ air quality campaign in Colorado's northern Front Range during the summer of 2014.

Student teams will then research one of three carbon gases (carbon monoxide, carbon dioxide, and methane) that the NOAA Mobile Laboratory monitors in order to gain an understanding of their various potential sources as well as their impact on air quality.

Engage (15 min.) *Interest in air quality is generated and students' current understanding of air pollution is assessed*

NPR radio interview: As a class, listen to the story and "meet" Gaby Pétron, an atmospheric scientist and learn about her research work in air quality:

http://www.npr.org/2012/05/17/151545578/frackings-methane-trail-a-detective-story

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!

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Gabrielle Pétron, CIRES/NOAA Atmospheric Scientist
Gaby is a Sustainability Research Networks (SRN) Air Quality Researcher. Gaby and her research team employ a Mobile Lab to collect and analyze air samples along rural roads in northeastern Colorado near oil and gas equipment, landfills and animal feeding operations. A primary focus of their research is to try to identify the possible sources of methane emissions.
After listening to Gaby's interview, participate in a teacher-led class discussion to learn more about the details of how Gaby conducts her atmospheric research.

- Why do we call carbon monoxide, carbon dioxide, and methane "carbon gases"?
- Why do you think scientists are interested in knowing the levels of carbon gases in the air?
- What is "Picarro"? What does it measure?
- What is does the term "spike" mean in regards to measuring gases in the atmosphere?

Scientists Gaby Pétron and John Kofler outside the Mobile Lab (Image: CIRES)


NOAA Mobile Laboratory (Image: CIRES)

NOAA Mobile Laboratory Introduction:
Use the following script to provide background information and context for the module activities:
Ask: What is a road trip? Has anyone ever been on a road trip? (Share responses)
Say: During this module we are going on a virtual road trip. This road trip is going to be a bit different. We're are going to jump in the National Oceanic and Atmospheric Administration's (NOAA) Mobile Laboratory for a scientific road trip!

The Mobile Lab can be driven anywhere a family van can go. What makes this van unique is that it is fully equipped with research instruments. These instruments measure the real-time levels of various gases in the ambient air. Every few seconds, the Mobile Lab's instruments record the levels of specific gases in the surrounding air. A company named Picarro builds one of these instruments and it measures the CO_2 (carbon dioxide), CO (carbon monoxide), CH_4 (methane), and H_2O (water vapor, water in gaseous form) levels in the air with high precision. The Picarro instrument displays this real-time information on a computer screen between the driver and passenger seats inside the NOAA Mobile Lab and the Picarro Instrument:

Carbon monoxide, carbon dioxide, methane, and water vapor exist naturally in the air (CO_2 in much greater quantities than CO or CH_4). The purpose of the Mobile Lab drives is to detect **spikes** (higher than average readings) in levels of these gases in the atmosphere and identify potential sources of the elevated spikes.

The NOAA Mobile Laboratory does not directly measure emissions, which are gases that are emitted from a source. The Picarro instrument cannot show exactly how much of a particular gas is emitted from a nearby source. Instead, it measures the levels of gases in the ambient air that flow through the Picarro instrument and can detect spikes in levels of gases. The gas levels are influenced by emissions from various sources as well as by wind speed and direction, weather conditions, etc. Scientists can do "detective work" to analyze the Picarro data and discover the sources that are likely responsible for a spike in a level of a carbon gas.

Before we start our scientific road trip, you have been selected to be part of scientific teams. Your team will research one of the three carbon gases that the Mobile Lab's "Picarro" instrument monitors - CO, CO_2, or CH4. We will then share our knowledge as a class to learn more about the potential sources of CO, CO_2, and CH_4 and how they impact air quality.

Instruments Inside the NOAA Mobile Laboratory:


Front: Picarro instrument & air collection flasks


Ozone monitor


Back: Air monitoring equipment


Air monitoring on the move!

(Images: NOAA)

Explore (35 min.): *Students conduct basic research to explore carbon gases related to air quality.*

Researching Carbon Gases:

1. Your teacher has grouped students into air monitoring research teams (two CO, two CO_2, and two CH_4 research teams).
   Divide the class into the six pre-determined research teams (two CO, two CO_2, and two CH_4 research teams). Hand out one copy of the "1.4 Mobile Lab" investigation student guide to each student (students will work collaboratively but will record their own answers individually).

2. For the "Carbon Gas Research" activity, your team will work collaboratively but you will record your own answers. For this activity, complete only the information for your group's assigned carbon gas (carbon monoxide, carbon dioxide, or methane).
   Each team completes questions #1-5 on the "Carbon Gas Research" for their assigned carbon gas. Provide copies of printed information and/or bookmarked tablets/computers for students to complete the worksheet and understand the background information on their carbon gases.

3. Use the provided copies of printed information and/or bookmarked tablets/computers for your team to complete the worksheet and understand the background information on their carbon gases. Research and complete questions #1-5 on the worksheet.

   Carbon gases "fast facts" (one per student, based on their assigned carbon gas):
   CO: http://www.epa.gov/airquality/carbonmonoxide/
   CO_2: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html
   CH_4: http://epa.gov/climatechange/ghgemissions/gases/ch4.html

4. As part of a class discussion, share your team's responses to questions #1-5. Your teacher will summarize and write each group's responses under the appropriate label "Carbon Monoxide", "Carbon Dioxide", or "Methane" on a whiteboard/poster board/butcher paper. Teams can refer back to this posted information as they complete the second activity.

Carbon Gas Research:
Use the websites and/or printed information provided to answer the following questions:

1. Circle the carbon gas that your team is researching:
   Carbon monoxide **Carbon Dioxide** **Methane**
2. Write the chemical symbol of your carbon gas:
3. Is this carbon gas naturally occurring in Earth's atmosphere? If so, give an example(s) of where this carbon gas is found in nature.
4. Do human activities (sources) emit (release) this carbon gas into the atmosphere? If so, give an example(s) of human activities that emit this carbon gas
5. Can this carbon gas affect human health and/or the environment? If so, give one example of human health and/or environmental effects caused by this carbon gas.

After team research is complete, review questions #1-5 and briefly summarize and write each group's responses for the carbon gases under the titles "Carbon Monoxide", "Carbon Dioxide", and "Methane" on a whiteboard/poster board/butcher paper posted in a visible location. Guide the class in completing and/or correcting any misconceptions regarding carbon gas sources. It is important that CO and CO_2 sources include mobile sources (cars, trucks etc.) and that CH_4 sources include oil & gas wells (natural gas production), livestock (animal feedlots) and landfills. Teams can refer back to this posted information as they complete the next activity

Primary carbon dioxide (CO_2) sources include electricity generation, mobile sources (cars, trucks etc.), and industry. CO_2 is both a naturally occurring and anthropogenic greenhouse gas and is designated by the EPA as an air pollutant. CO_2 is the most significant anthropogenic greenhouse gas contributing to climate change. In 2013, levels of CO2 in the atmosphere reached 400 ppm at the remote Mauna Loa Observatory in Hawaii.

Methane (CH_4) sources include natural gas and petroleum systems (oil & gas wells, etc.), livestock (animal feedlots), and landfills. CH_4 is the second most significant anthropogenic greenhouse gas. Methane exists at significantly lower levels in the atmosphere than CO_2, but it has greater global warming potential than CO_2, meaning CH_4 is significantly better at trapping heat. As mixing levels of CO_2 and CH_4 increase, more heat is trapped in the atmosphere resulting in a higher average global temperature.

Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes or produced in the atmosphere during the incomplete oxidation of more complex carbon molecules and is designated by the EPA (Environmental Protection Agency) as an air pollutant. In developed countries, particularly in urban areas, the majority of CO in ambient air (outdoor air in the surrounding environment) is emitted by cars and trucks, which are known as "mobile sources". CO can cause negative health effects by reducing oxygen delivery to the body's organs (such as the heart and brain). At extremely high levels, CO can cause serious health effects or even death. EPA regulation on CO emissions from mobile sources has helped in bringing CO levels down in urban areas.

Additional Sources:
http://www.esrl.noaa.gov/gmd/aggi/
http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html
http://www.epa.gov/airquality/urbanair/
http://www.cdc.gov/niosh/idlh/630080.html

Day 2
In the second activity, your team's goal is to predict the potential sources for carbon monoxide, carbon dioxide, and methane that are measured in the air. You will first analyze data plots from the Picarro instrument and then analyze the Mobile Lab drive maps, which both measure CO, CO_2, and CH_4 in the surrounding (ambient) air. Finally, it will be revealed which Picarro data plots match the carbon sources located at each monitoring location. Test your team's ability to see how well you can trace the tracks of carbon gases back to their potential sources in this carbon gas CSI investigation!

Explain (15 min.): *Students construct their understanding of carbon gas sources and develop evidence-based explanations using carbon gas data.*

Carbon Gas Data Plot Analysis:
Using the Picarro graphs and monitoring location map, teams will identify and record the maximum level (spike) for the main carbon gas at each data plot section and predict which monitoring location is the potential source for each data plot. Students record their responses in the "Carbon Gas Prediction & Data Analysis" table (columns 2, 3, 4):

1. Observe the "Picarro Carbon Gas Levels" graphs for July 21 and July 22, 2014. Read the data plots by looking at the key, the x and y-axes scale and labels, and interpreting the parts per million (ppm) or parts per billion (ppb) levels for each of the three carbon gases. The carbon gas data plots are color-coded with their corresponding y-axes (e.g. Methane data and its y-axis are both red).

   Note that the time that passes on the data plot (x-axis) does not relate to distance driven by the mobile lab. The mobile lab will often stop and spend time at a particular location. Also note that the two graphs have a different scales for levels of CH_4 (July 21st goes up to 20 ppm and July 22nd up to 10 ppm.

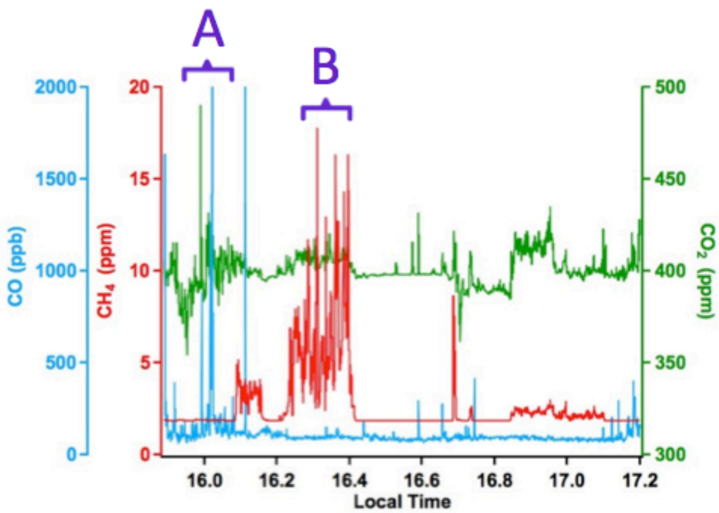
   Project the Picarro graphs and explicitly demonstrate to students how to read the graph emphasizing the double y-axes and color-coded carbon gas levels, the data plot sections (A - D), and reinforcing the units of measurement, etc. Ask students to compare/contrast and summarize the patterns they observe in the graphs.

2. Working as a group, look at the A, B, C, D data plot sections on the Picarro graphs. For each data plot section, identify the carbon gases that are present and their highest spike (maximum level). Record each gas present and its approximate highest value (spike) plus the unit of measurement (ppm or ppb). (columns 2-4). Share your results with the class.

   Ask students groups to share their observations for each of the four data plot sections. For each data plot A – D, write the carbon gases and their corresponding maximum level and unit on the board in order to reach class consensus. Remind groups to check that all team members have the data recorded accurately.

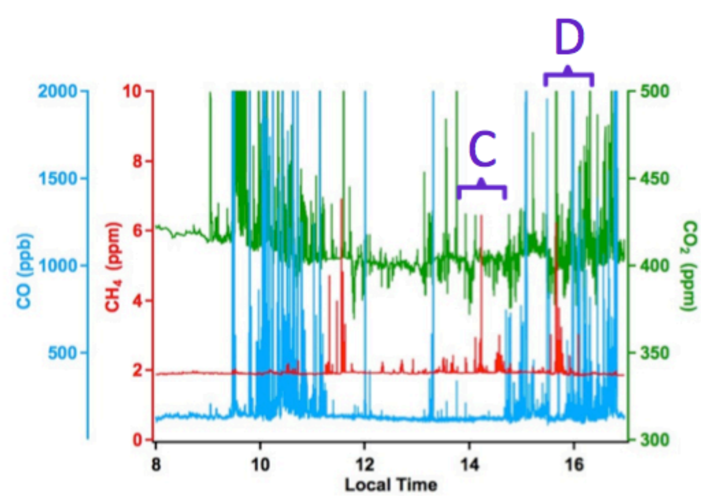
Picarro Carbon Gas Spike Maximum Levels (approx. ppm/ppb) (e.g. CH_4 – 7 ppm)			
Data Plot	CO_2 (ppm)	CO (ppb)	CH_4 (ppm)
A	490	2000	2 (background level)
B	410 (background level)	100 (background level)	18
C	430	200	7
D	500 (elevated levels nearby)	2000 (elevated levels nearby)	6

Carbon Gas Levels Recorded by Picarro – July 21st (Day 1)



Key:
A = Mobile Lab Measurement Data Plot
__ = Carbon Dioxide (CO_2) Levels
__ = Carbon Monoxide (CO) Levels
__ = Methane (CH_4) Levels

Carbon Gas Levels Recorded by Picarro – July 22nd (Day 2)



Key:
A = Mobile Lab Measurement Data Plot
__ = Carbon Dioxide (CO_2) Levels
__ = Carbon Monoxide (CO) Levels
__ = Methane (CH_4) Levels

(Source: NOAA)

Explain
Carbon Gas Source Predictions:
Next, your group will review the monitoring location map, which identifies potential sources of carbon gases, and predict which data plot matches with each monitoring location.

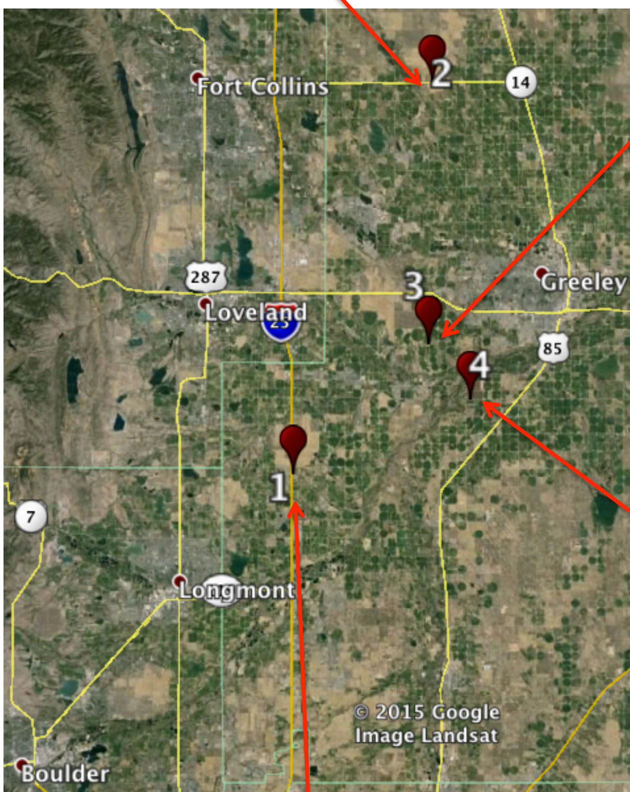
3. Review the "Mobile Laboratory Monitoring Locations" map. Using the map, write the main "Main Carbon Gas Source" for monitoring locations 1, 2, 3, and 4 (column 2)

4. Based on the previous research of carbon gases and the Picarro carbon gas data plots, predict which monitoring location (1 – 4) most likely is the potential carbon gas source measured in the surrounding (ambient) air data plot (A – D). Complete the "Predicted Data Plot Match" section (column 3)

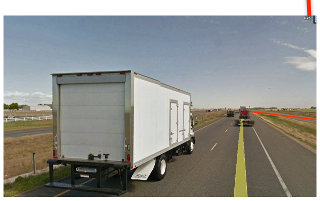
NOAA Mobile Laboratory Air Quality Monitoring			
Monitoring Locations	Main Carbon Gas Source (e.g. Landfill)	Predicted Data Plot Match (A - D)	Actual Data Plot Match (A - D)
1	I-25 / Roadway	Team dependent	A = CO & CO_2
2	Landfill	"	B = CH_4
3	Oil & Gas Wells	"	C = CH_4
4	CAFO / Livestock	"	D = CH_4 (CO & CO_2 road nearby)

2: Landfill
Conditions: This is a very large, active landfill and on this day there was limited road traffic.

3. Oil and Gas Wells
Conditions: These wells are located in a rural area in Weld County. Road traffic is limited at this location.



4: Cow CAFO (controlled animal feeding operation)
Conditions: This cow feedlot is located near a major road. There was high traffic on this day.



1: I-25 Corridor
Conditions: Consistent traffic, including passenger cars and 18-wheeler semi-trailer trucks.

Mobile Laboratory Monitoring Locations

(Source: NOAA)

Elaborate (20 min.): *Students deepen and expand their understanding of the relationship between carbon gases and air quality by applying their understanding in terms of atmospheric monitoring.*

Analyzing Carbon Gas Data:

5. Analyze the "NOAA Mobile Lab Drive" graphs. Which areas on the map have high and low measurements for each of the carbon gases? Compare the mobile lab drive data with the original predictions of the potential carbon gas source for each monitoring location (1 – 4). Based on this new data, change any predictions in the "Predicted Data Plot Match" section, if needed (column 3).

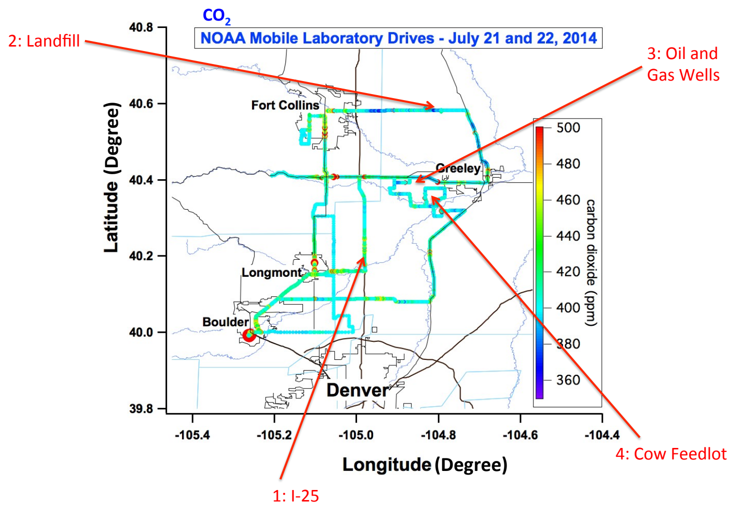
   Ask clarifying questions: Example question: "Team One, which Picarro data plot section (A – D) had the greatest spike (highest level) in methane and which monitoring location do you predict this spike of methane was measured at 1, 2, 3, or 4?" Example team response: "Data plot B had the greatest spike in methane and we predict that the source was the large landfill next to monitoring location 2."

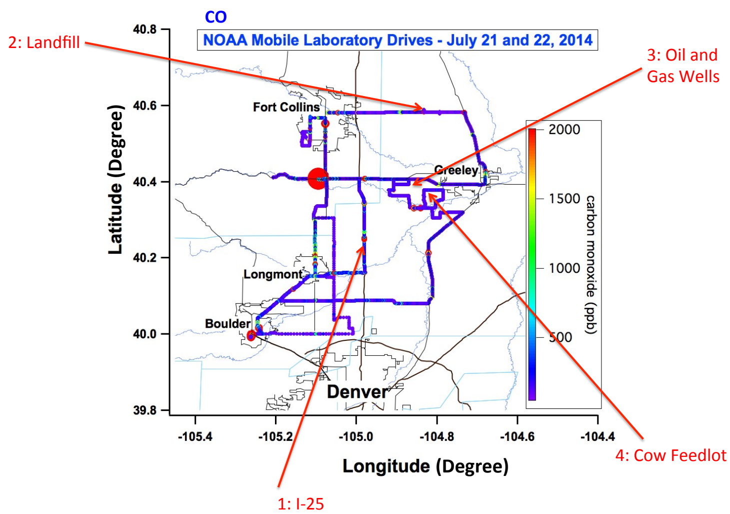
   Ask follow-up questions: "Team Two, what other factors do you think might affect recorded levels of carbon gases at the monitoring locations? (e.g. distance of monitoring location from carbon gas sources, proximity to roadways, number of cars on the road, wind speed and other atmospheric conditions, instrument calibration, etc.).

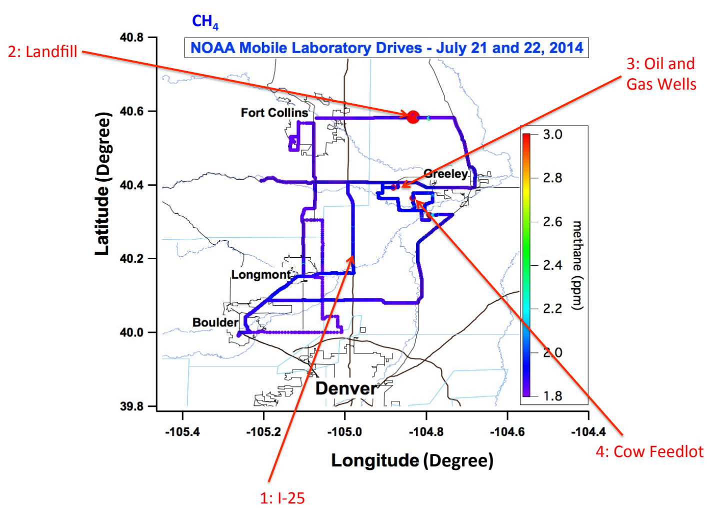
6. Next, the actual results are revealed as to which data plots correlate to which monitoring locations. Complete the "Actual Data Plot Match" section with the correct data (column 3). How accurately did your group's prediction of data plots and carbon gas sources match the actual results of the carbon gas levels associated with each monitoring location (column 4)?

   1-A, 2-B, 3-C, 4-D: 1 is I-25 (A), 2 is Landfill (B), 3 is an Oil & Gas well (C), an 4 is an Animal Feedlot (D). Reinforce with students the carbon gas sources at each monitoring location (roadways, oil & gas wells, landfills, animal feedlots, etc.).

   Ask students what realizations they have made based on the data provided and address any questions or misunderstandings they may have. Do you think there are any carbon gas sources that are not well detected by the NOAA Mobile Laboratory (power plants generating CO_2, etc.)? Discuss ideas for other air quality investigations that could be researched based on the results provided.


CO2
NOAA Mobile Laboratory Drives - July 21 and 22, 2014
2: Landfill
3: Oil and Gas Wells
4: Cow Feedlot
1: I-25
Fort Collins
Greeley
Longmont
Boulder
Denver
Latitude (Degree)
Longitude (Degree)
carbon dioxide (ppm)
500
480
460
440
420
400
380
360
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4


CO
NOAA Mobile Laboratory Drives - July 21 and 22, 2014
2: Landfill
3: Oil and Gas Wells
4: Cow Feedlot
1: I-25
Fort Collins
Greeley
Longmont
Boulder
Denver
Latitude (Degree)
Longitude (Degree)
carbon monoxide (ppb)
2000
1500
1000
500
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4


CH4
NOAA Mobile Laboratory Drives - July 21 and 22, 2014
2: Landfill
3: Oil and Gas Wells
4: Cow Feedlot
1: I-25
Fort Collins
Greeley
Longmont
Boulder
Denver
Latitude (Degree)
Longitude (Degree)
methane (ppm)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4

(Source: NOAA)

Answer Key:
The answers are designed to engage further discussion and provide some clarification and explanation for the atmospheric detective work the students have conducted.

1 = A I-25 Corridor
This section of the Mobile Laboratory data was taken along the I-25 corridor. The data indicates higher levels of CO as well as CO_2 largely from the combustion of fossil fuels from cars. The graph indicates CO spikes of up to 2000 ppb (almost 20 times the normal background levels of 100ppb) while CO_2 is also elevated with a spike of almost 500 ppm (background is ~400ppm). CO results from the incomplete combustion of fossil fuels and CO emissions have been reduced over the past years because of greater regulations on car emissions as well as more efficient vehicles. Unlike CO, CO_2 cannot be reduced by more strict pollution control techniques. Burning less fossil fuel is the only way to reduce CO_2 emissions (traveling less, buying a car with greater gas mileage, using different fuel-ethanol additives). Engine combustion does not emit CH_4 and this is why there are only spikes in CO and CO_2 at this location.
Additional Resources:
http://www.infocusmagazine.org/3.2/env_co.html

2 = B Landfill
This section of the data is representative of a landfill. As one of the main urban contributors of CH_4, landfills are an important piece to the overall puzzle of air quality. According to the graph, CH_4 is high with levels reaching 3-18 ppm (background is roughly 1.8ppm) at this location. There are no additional CO or CO_2 (above background). The spike in methane is due to decomposition and composting that is occurring at the landfill site. Landfills are constantly being adapted in order to reduce methane emissions. Check the resources below for additional information regarding landfills. One important thing to note here is that after observing a spike in CH_4 it is common for the mobile lab to stay in the location of the spike in order to gather further information about the spike and its potential sources.
Additional resources:
http://www.epa.gov/methane/lmop/basic-info/index.html
http://www.esrl.noaa.gov/gmd/ccgg/isotopes/sampling.html

3 = C Oil & Gas Well Site
There are over 50,000 oil and gas wells in the county surrounding this well pad. Researchers can see potential evidence that this site is leaking because of the 7-ppm spike in CH_4 that is picked up by Picarro. Picarro cannot distinguish between emissions sources including oil and gas sites, feedlots or landfills (however, flasks of air can be analyzed at the lab for isotopes and other present gases to help determine sources).

This means that it is important to observe the surrounding area, wind direction, and other elements for clues about the source of the carbon gas. According to Picarro there are elevated levels of CO and CO_2 near this site as well. CO and CO_2 at oil and gas sites can result from many sources including the incomplete combustion of stacks, flares, or vehicles. Can you locate potential sources of CO and CO_2 on this well pad? (Look to black stacks and combustors)
Additional Resources:
http://www.ogj.com/articles/2015/01/white-house-orders-steps-to-curb-oil-and-gas-methane-emissions.html

4 = D CAFO

Another contribution to CH_4 in the Front Range is the large number of animal feedlots. Here we see a Picarro data spike in CH_4 between 2-6ppm. This cow CAFO, or Confined Animal Feeding Operation is a major source of the spike in CH_4. Cows' digestion process (enteric fermentation) and the decomposition of their manure are both contributors. But what about the CO and CO_2 levels at this location? What do elevated levels of CO and CO_2 indicate again? Yes, the feedlot is located along a busy road. The CO and CO_2 are likely related to vehicle traffic along the road.
Additional Resources: http://epa.gov/climatechange/ghgemissions/gases/ch4.html
http://whatsyourimpact.org/greenhouse-gases/methane-sources

Additional resources for information on carbon gases:
CO:
http://www.cpsc.gov/en/Safety-Education/Safety-Education-Centers/Carbon-Monoxide-Information-Center/Carbon-Monoxide-Questions-and-Answers-/
CO_2:
http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/
http://www.esrl.noaa.gov/gmd/ccgg/trends/
CH_4:
http://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/
http://www.esrl.noaa.gov/gmd/ccgg/globalview/ch4/ch4_intro.html

Evaluate (15 min.): *Students and teachers have opportunities to assess students' understanding of carbon gas sources and their relationship to air quality.*

Carbon Gases & Me Think-Pair-Share:
Briefly review your "1.4 Mobile Lab" investigation packet. As a class, think, pair, and share ideas and then individually write your own responses to the following questions. Each response should be at least one paragraph in length, written in complete sentences using correct capitalization, grammar, punctuation, and spelling.

1. How do the sources of carbon gases (energy production, landfills, animal feedlots, and roadways) relate directly or indirectly to your daily life (think about your needs and uses of electricity, garbage collection, food sources, transportation, etc.). Explain.

2. What are ways that you can help reduce the contribution of anthropogenic (human made) carbon gases (CO, CO_2, and CH_4) in the atmosphere (think about saving energy in your home, recycling, food choices, walk/bike/bus/carpool, etc.)? Explain.

Additional Resources:
Differentiation & Extensions:
The following resources are part of the online Climate Literacy & Energy Awareness Network (CLEAN). Explore the carbon cycle and understand its relationship between the various carbon reservoirs on Earth and climate change:

- Interactive Carbon Cycle: This interactive animation focuses on the carbon cycle and includes embedded videos and captioned images to provide greater clarification and detail of the cycle than would be available by a single static visual alone.

- Carbon Cycle Game: In this interactive, regionally-relevant carbon cycle game, students are challenged to understand the role of carbon in global climate change. They imagine that they are carbon molecules and travel via different processes through carbon reservoirs on the Colorado Plateau (the Four Corners area of Arizona, Colorado, New Mexico and Utah). This game can be adapted to other regions.

- Air: Fuel for Thought: This lesson plan engages students in a real-life exploration of climate change as it is affected by greenhouse emissions from vehicles. The aim of this activity is for students to realize the impact of vehicle use in their family and to give students the opportunity to brainstorm viable alternatives to driving.

- Changing Planet: Thawing Permafrost and Methane: This video examines the thawing of permafrost due to changes in climate and shows examples of the impacts that warming temperatures have on permafrost in the Arctic, including the release of the greenhouse gas methane. Dramatic results are shown, including sinkholes forming on the landscape and beneath buildings, roads, and other infrastructure, causing some communities to relocate. Follow with Changing Planet: Permafrost Gas Leak: This is a multi-faceted activity that offers students a variety of opportunities to learn about permafrost through an important sink and source of greenhouse gas (methane), about which most students living in lower latitudes know little.

- Show the CO_2 Movie that illustrates the history of carbon dioxide levels in Earth's atmosphere from 800,000 years ago until January 2014.
  Verbal discussion question: Do you think quality is a local issue, a global concern or both? Explain.
  Air quality is both a local issue and global concern since air and its pollutants directly impact a local area and continue to move throughout the Earth's atmosphere.

References & background information:

- Using CIRES Spheres Magazine to teach Common Core "Reading Informational Text": http://cires.colorado.edu/education/outreach/ICEE/spheres.html
- CIRES 'Spheres' article "Into Thin Air" (pp. 12-15) and additional articles:
  http://www.scribd.com/doc/210286678/Energy-and-Environment-2014
  http://cires.colorado.edu/science/spheres/air/pollution_hunters.html
  http://cires.colorado.edu/news/press/2012/Colorado_oil.html
  http://cires.colorado.edu/news/press/2014/airbornemeasurements.html
- NOAA/ESRL GMD Teaching Resources: http://www.esrl.noaa.gov/gmd/education/
- Basics of the Carbon Cycle and the Greenhouse Effect:
  http://www.esrl.noaa.gov/gmd/ccgg/basics.html
  Annual Greenhouse Gas Index (AGGI) graph: http://www.esrl.noaa.gov/gmd/aggi/
- NOAA Carbon Tracker: http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/
- Total CO_2 emissions footprint comparison by nation and per capita info graphic: http://www.psmag.com/nature-and-technology/tracking-climate-change-24435http://www.esrl.noaa.gov/gmd/education/
- Denver Post Article: http://www.denverpost.com/business/ci_26942340/researchers-assess-emissions-from-colorado-oil-and-gas
- Methane Build-up in the Atmosphere article: http://arctic-news.blogspot.com/2014/04/methane-buildup-in-atmosphere.html
- UCAR Center for Science Education Air Quality Teaching Box: http://scied.ucar.edu/air-qualityhttp://scied.ucar.edu/air-qualityhttp://scied.ucar.edu/air-quality

- Download lesson files (pdf):
  - "1.4 Carbon Gas Research" Worksheet
  - Download "1.4 Packet", "1.4 Pictures", and "1.4 Supplemental Maps" activity folders