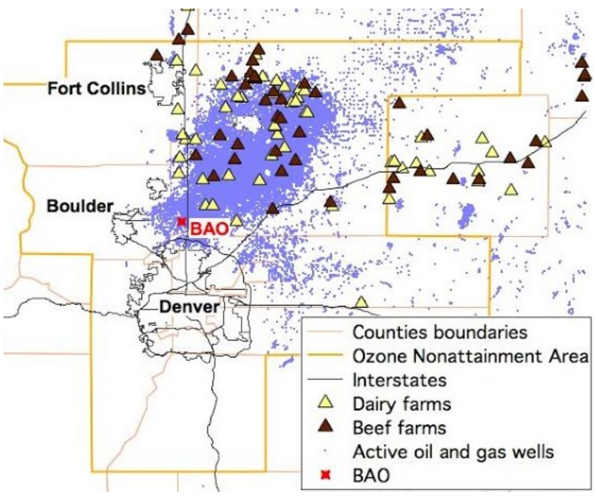
Name: ____ Date: __________

1.4 Carbon Gases CSI: Mobile Lab, Methane & More – Student Investigation 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)

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
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!

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)

(Image: CIRES)

NOAA Mobile Laboratory Introduction:
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

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
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).

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).

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.

Explore
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.

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

Carbon Gas Data Plot Analysis:

Your team will now take on the role of atmospheric scientists! As a group, analyze the four data plots on the Picarro instrument graphs to determine the highest levels (spikes) of carbon gases that were measured in the surrounding (ambient) air.

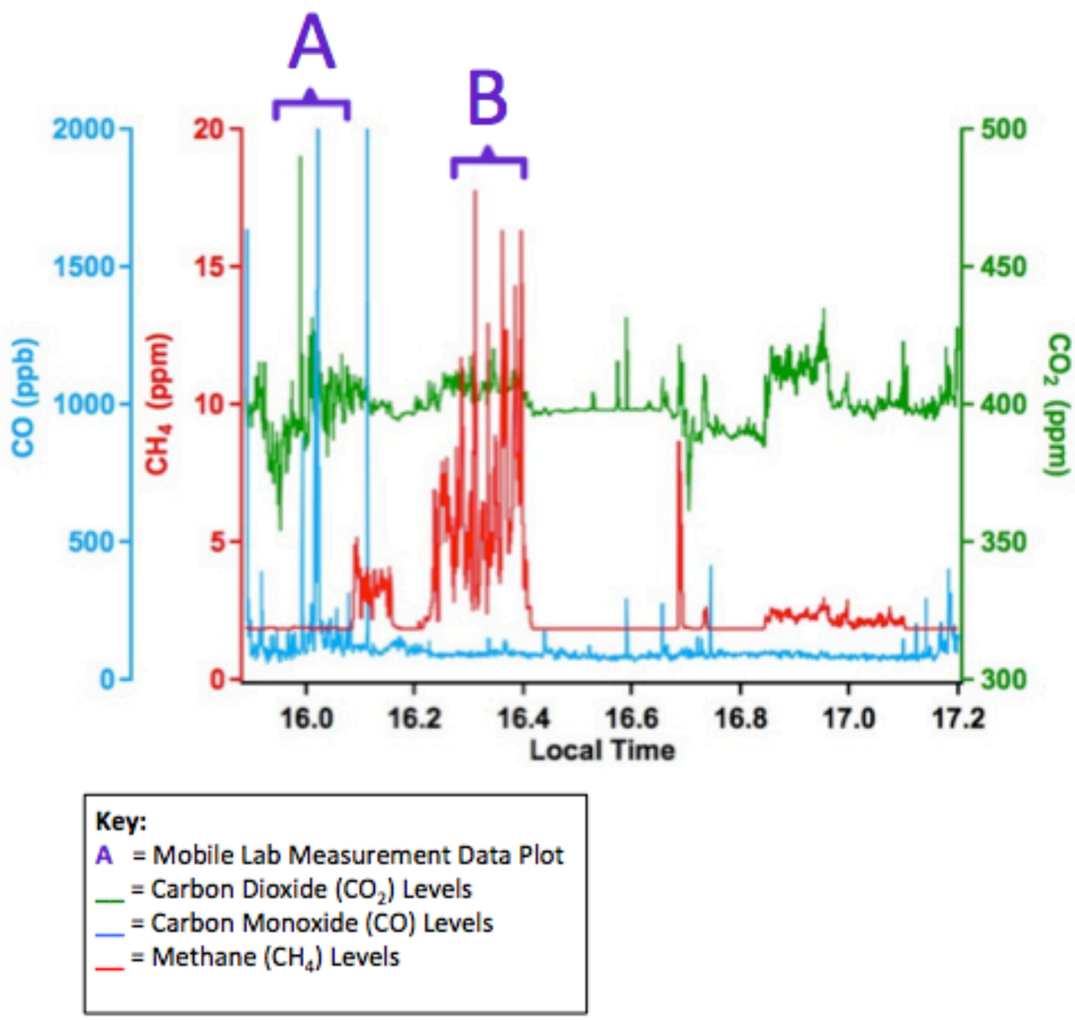
1. Observe the "Picarro Carbon Gas Levels" graphs for July 21 and July 22, 2014. Read the data plots by looking at the key, the x and y-axes scale and labels, and interpreting the parts per million (ppm) or parts per billion (ppb) levels for each of the three carbon gases. The carbon gas data plots are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

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.

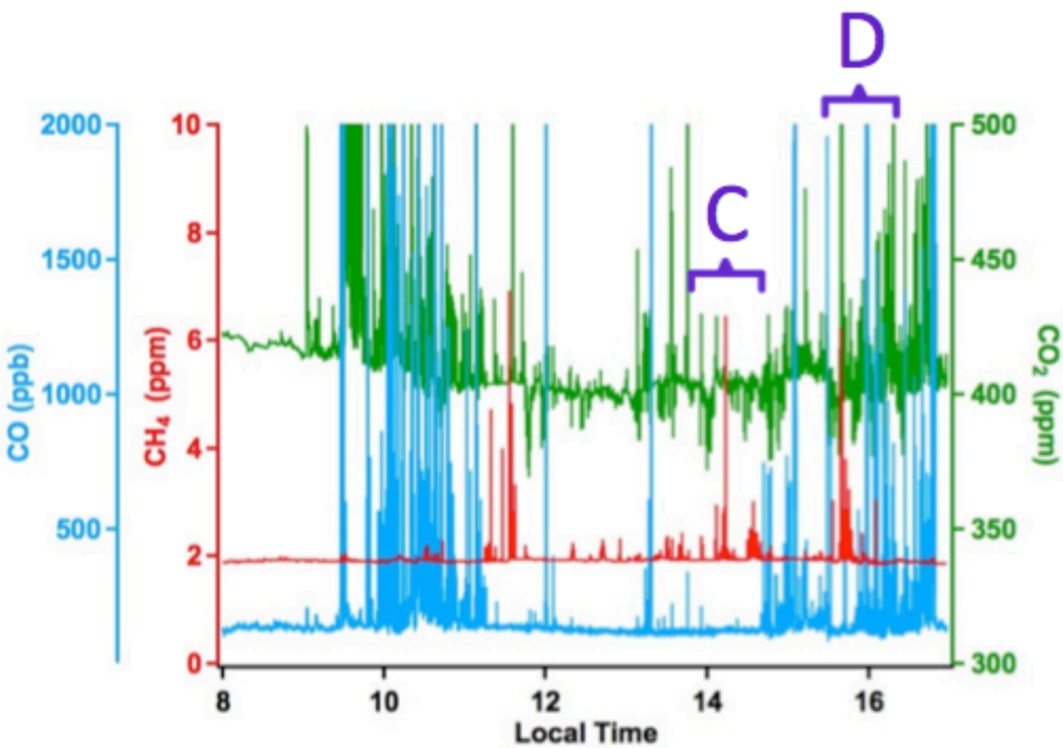
Picarro Carbon Gas Spike Maximum Levels (ppm/ppb) (e.g. CH_4 – 7 ppm)			
Data Plot	CO_2 (ppm)	CO (ppb)	CH_4 (ppm)
A			
B			
C			
D			

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



(Source: NOAA)

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)

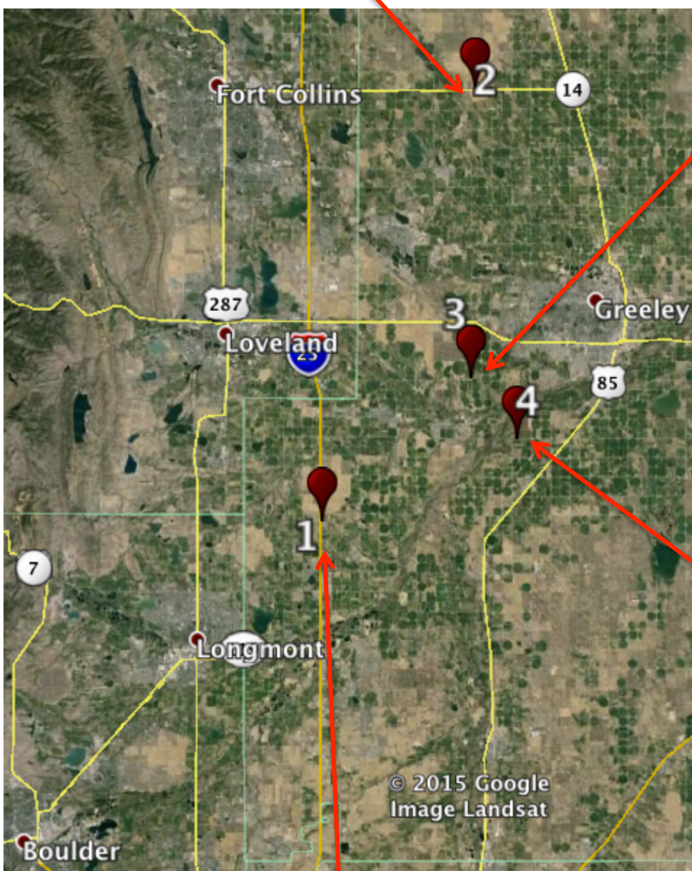
NOAA Mobile Laboratory Air Quality Monitoring			
Monitoring Locations	Main Carbon Gas Source (e.g. Landfill)	Predicted Data Plot Match (A - D)	Actual Data Plot Match (A - D)
1			
2			
3			
4			

Elaborate
Analyzing Carbon Gas Data:
Read the following instructions and then fill in the relevant information:

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).

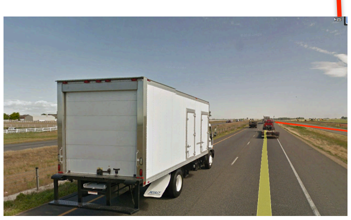
6. Next, the actual results are revealed as to which data plots correlate to which monitoring locations. Complete the "Actual Data Plot Match" section with the correct data (column 3). How accurately did your group's prediction of data plots and carbon gas sources match the actual results of the carbon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

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.

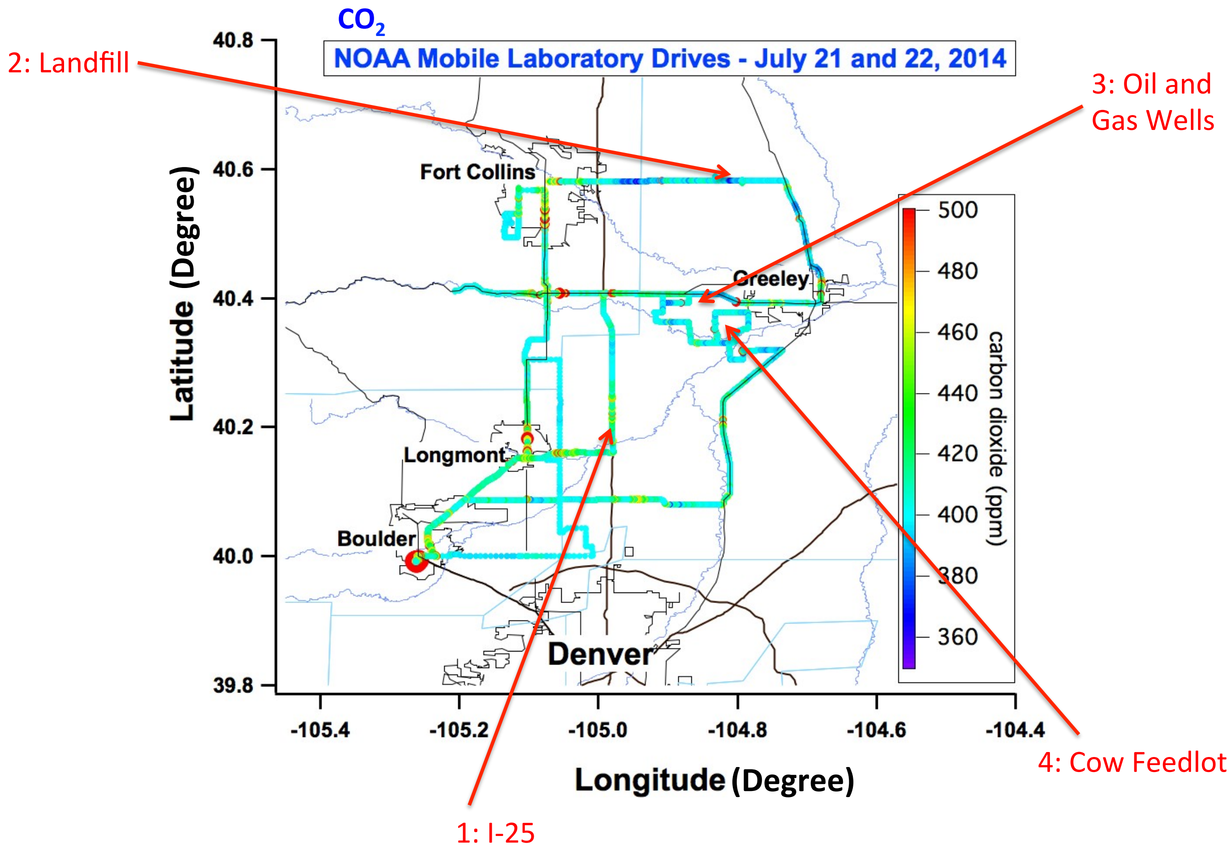
4: Cow CAFO (controlled animal feeding operation)
Conditions: This cow feedlot is located near a major road. There was high traffic on this day.



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

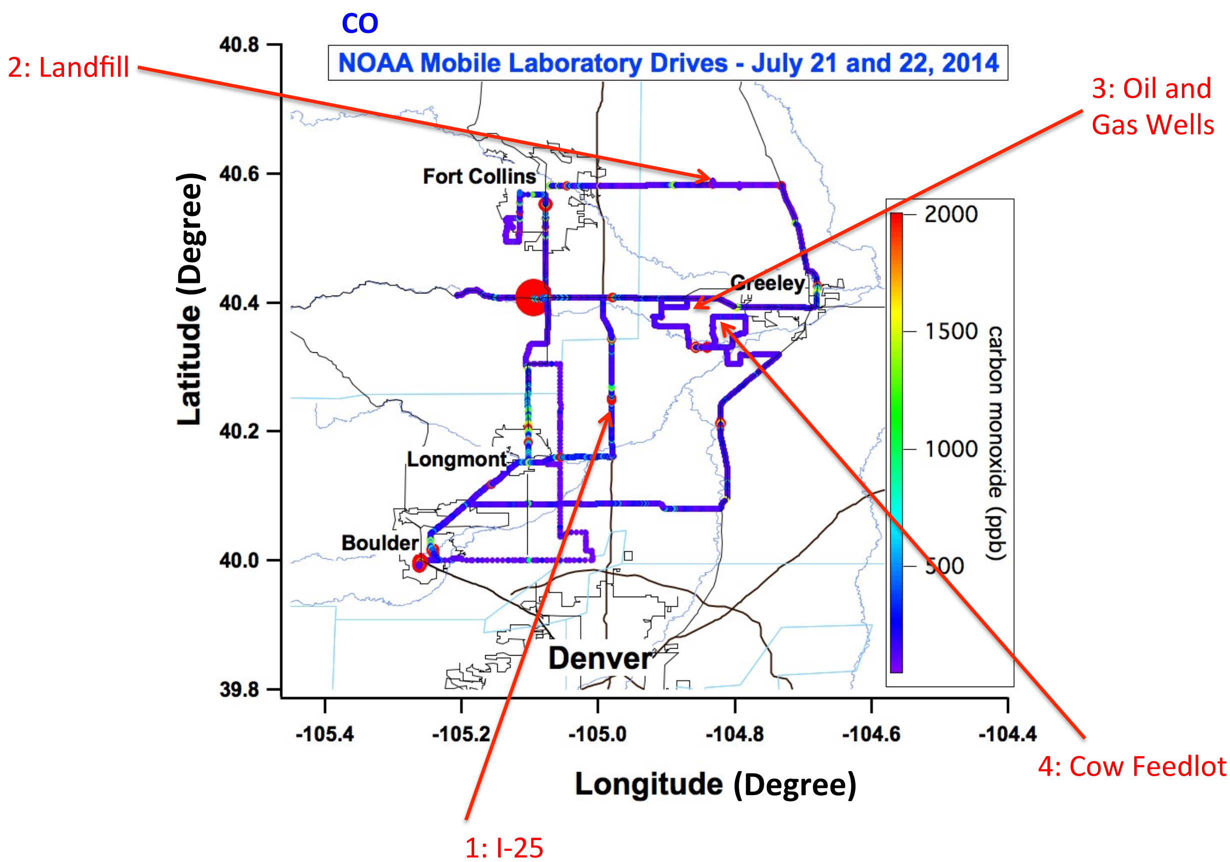
Mobile Laboratory Monitoring Locations

(Source: NOAA)

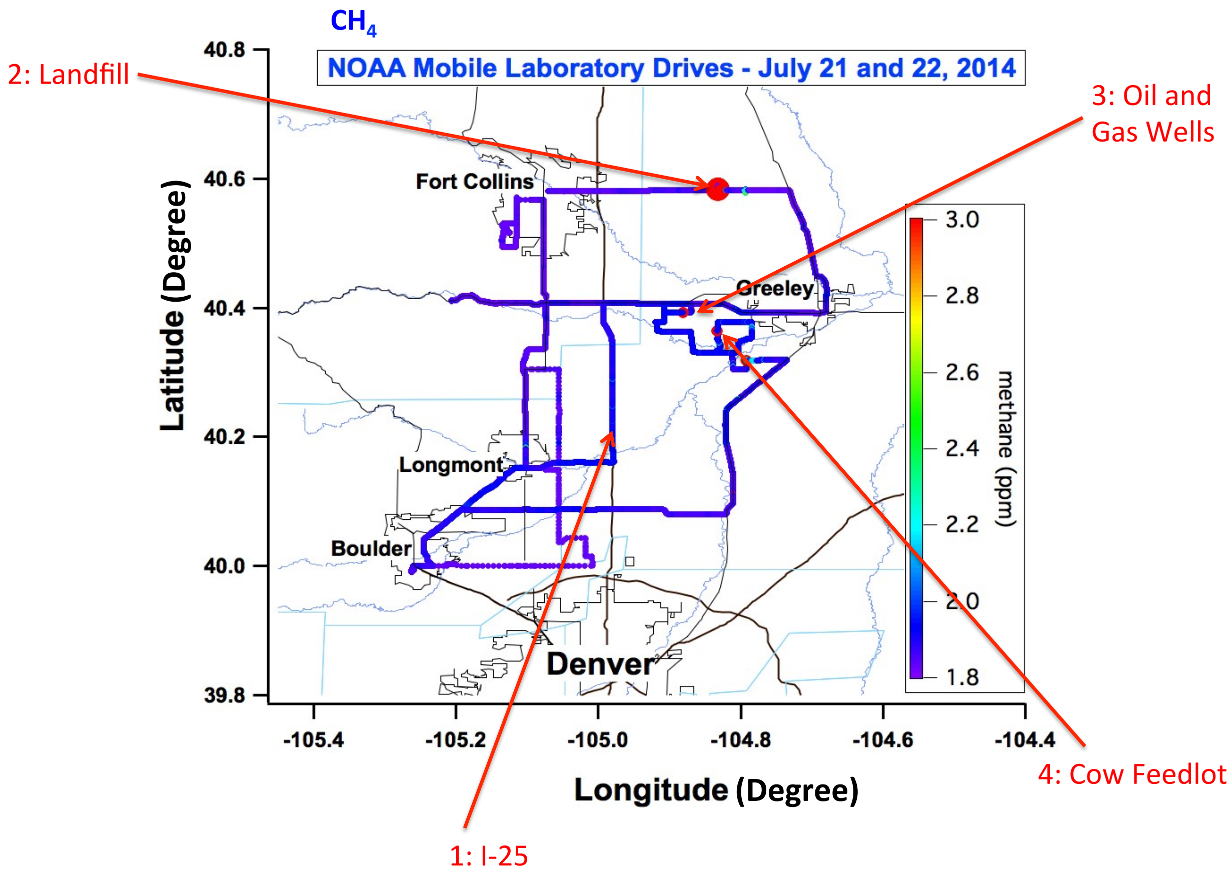


CO2
NOAA Mobile Laboratory Drives - July 21 and 22, 2014
2: Landfill
3: Oil and Gas Wells
4: Cow Feedlot
1: I-25
Fort Collins
Greeley
Longmont
Boulder
Denver
Latitude (Degree)
Longitude (Degree)
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4
500
480
460
440
420
400
380
360
carbon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

(Source: NOAA)


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)
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4
2000
1500
1000
500
carbon monoxide (ppb)

(Source: NOAA)


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)
40.8
40.6
40.4
40.2
40.0
39.8
-105.4
-105.2
-105.0
-104.8
-104.6
-104.4
3.0
2.8
2.6
2.4
2.2
2.0
1.8

(Source: NOAA)

Evaluate
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.