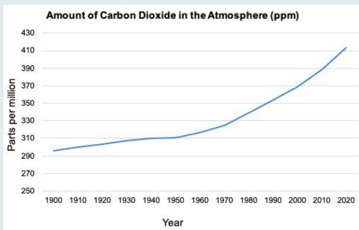
LESSON 6: Are there any changes in the air that could be related to rising temperatures?

PREVIOUS LESSON *We used our key models ideas to explain how changes in temperature have an impact on our case site communities. We revised our explanations using peer feedback and applied our key model ideas in an Alaskan assessment transfer task. Finally, we were curious as to what would be causing the temperatures to change.*

THIS LESSON

INVESTIGATION

1 day



We recall our understanding about the molecules that make up air and look at data that shows the concentration of those molecules over time. We continue wondering if changes in the air are related to the rise in temperatures. By looking at the data, we build our understanding of the meaning of parts per million and figure out how to find the percent change in the quantity of these gases over time. We notice that, while some gases have not changed at all, some have changed very little, while other gases show an unusual increase over the 100-year period. Based on these new findings, we wonder if the gases that are rising are related to or causing the temperatures going up.

NEXT LESSON *We will figure out if the gases that are increasing in the atmosphere are causing the temperature to rise. We will do this by comparing movement of different atmospheric gas molecules and apply that to heat transfer.*

BUILDING TOWARD NGSS

MS-ESS3-1, MS-ESS3-3, MS-ESS3-4, MS-ESS3-5, MS-ETS1-2

WHAT STUDENTS WILL DO

6.A Apply mathematical concepts of ratio and percent to understand the quantity of and stability and/or change in the concentration of gases in the atmosphere over time.

WHAT STUDENTS WILL FIGURE OUT

- The atmosphere is made from different concentrations of gases.
- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**COMPARE THE MIXTURES OF GASES IN THE ATMOSPHERE** Have students recall and review the composition of gases that make up the atmosphere.	A-B	
2	6 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT PARTS PER MILLION** Facilitate a deeper discussion about the data displaying gas composition in parts per million. Support students in ratio reasoning to understand how amounts of gases are measured and converted into percents.	C	plastic bag, whiteboard or chart paper, markers
3	15 min	**ANALYZE CHANGES IN COMPOSITION OF GASES IN THE AIR** Distribute graphs for students to analyze changes in gases over time. Then have students work in partners or small groups to calculate the percent change for each gas and draw initial conclusions.	D-E	*Concentration of Gases in the Atmosphere Over Time* handout, calculator
4	15 min	**FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND ADD TO DQB** Bring students together to discuss new findings and add to the DQB.	F-G	sticky notes, markers, whiteboard or chart paper, DQB, Model Ideas list
5	3 min	**NAVIGATION** Prime students to further explore the causal link between gases that are on the rise and temperature change.		

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Concentration of Gases in the Atmosphere Over Time* handout • sticky notes • markers	• calculator	• plastic bag • whiteboard or chart paper • markers • DQB • Model Ideas list

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Have a large plastic bag on hand. This will be used to capture air as a visual to engage student thinking.

Alternate start to Lesson 6: In pilot studies of the anchor phenomenon and initial models to explain them, most students identified “pollution”, “carbon dioxide”, and “greenhouse gases” as the cause of temperature change. However, it is possible that students may believe that the Sun is getting warmer or closer to Earth or that the ozone hole is related to warming temperature. If your students identified these as possible warming mechanisms, explore them more using the Extension Opportunity located in *Exploring Possible Causes of Warming*.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

From early in the unit, students likely shared questions about how things in the air or gas molecules could be related to or causing the rise in temperature. Students may have already known about "pollution" or "carbon dioxide emissions" or even "greenhouse gases." In this lesson, students further explore how rising concentrations of gases in the atmosphere are related to rising temperatures, and in the next lesson, they will make sense of how those gases *cause* an increase in temperature. This lesson will have students explore the concentration of some permanent gases that make up our atmosphere and observe that some gases have increased at an unusual rate over time, while others have remained mostly stable. In order to make sense of the increase, students first need to develop an understanding of "parts per million." When looking at the total concentrations of gases by parts per million, both methane and carbon dioxide appear to be insignificant gases. By calculating the percent change, students then see that, while those gases are small in concentration and total quantity in the atmosphere, their percent change over time is unusually high, while other more abundant gases have changed very little. By the end of this lesson, students should wonder if the unusual increase of carbon dioxide and methane is actually *causing* the rising temperatures in the atmosphere.

Throughout this lesson, students will engage with mathematical reasoning about the phenomena. Students use ratio reasoning and percent to understand gas concentrations and their change over time. Two crosscutting concepts—Scale, Proportion, Quantity and Stability and Change—should be used by students to support their reasoning.

Where We Are NOT Going

This lesson does not explore the cause(s) of the changes in the concentration of these gases (Lesson 9) or which gases are considered greenhouse gases and their role in rising temperatures (Lesson 7). These ideas will be taken up in subsequent lessons. If students ask questions about these ideas, encourage them to add those questions to the DQB but avoid exploring them until later lessons.

There are interesting patterns to explore with changing water vapor and oxygen over time. Unfortunately, time does not permit for deeper investigation of changes in these two gases.

- Water vapor: With respect to water vapor, because overall atmospheric temperatures have risen, scientists have also observed increased percent of water vapor. Because water vapor is variable by geographic location, it is challenging to estimate "global average." If students are curious about the increase in water vapor, return to the ideas that students figured out in Lesson 3.
- Oxygen: Scientists have measured that atmospheric oxygen is declining over time. For the purposes of this lesson, oxygen is treated as a relatively "stable" gas because it has changed less than 1% over time. The science to explain this change is still tentative as scientists make sense of complex natural and human-generated causes for the decline. The change in oxygen concentration over time would make for an interesting extension opportunity for high interest learners should they express more curiosity about the decline.

LEARNING PLAN for LESSON 6

1 · COMPARE THE MIXTURES OF GASES IN THE ATMOSPHERE

6 min

MATERIALS: None

Navigation into the lesson. Say, *So far, we have figured out that change in temperature is related to issues, such as droughts, floods, wildfire, sea level rise, and sea ice melting. However, we still aren't sure why the temperature is increasing, or if it is related to global warming and climate change. We have been wondering if something is changing in the air that could be causing temperatures to go up. We have some ideas about gases in the air already that we've learned about before. Let's recall what we already know about them.*

Turn and talk about the composition of gases in the atmosphere. Display **slide A**. Ask the students to recall the gases that are found in the air. Students should recall ideas from the following units: *Storms Unit*, *Bath Bombs Unit*, and *Maple Syrup Unit*.

Record student responses and discuss relative composition. Bring students back together for a brief whole-group sharing. Ask students to share ideas as you record a public record. Students will likely mention oxygen, nitrogen, carbon dioxide, and water vapor. Ask for ideas about which gases are most abundant in the atmosphere. Students may recall from previous units that nitrogen and oxygen are the most abundant and that carbon dioxide makes up only a small amount.

Share percentages of gases in the atmosphere. Display **slide B**, which shows the percentages of the main gases making up the atmosphere: nitrogen, oxygen, carbon dioxide, water vapor, and other trace gases. Ask students to compare the chart to their responses. Students should notice/confirm that the graph shows a higher percentage of nitrogen, oxygen as the second highest, and that carbon dioxide, water vapor, and other gases make up a very small percentage of the atmosphere.

2 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT PARTS PER MILLION

6 min

MATERIALS: science notebook, plastic bag, whiteboard or chart paper, markers

Facilitate a discussion of parts per million and what that means as a unit of measurement. Continue to display **slide B**. Tell students that the pie chart is one way to show the concentration of gases that make up our atmosphere by percent. Say, *OK, so we know that there are percentages of these gases in the atmosphere, but how did scientists figure out these percentages anyway? It seems challenging to measure gas molecules in something as large as the atmosphere. Scientists have really interesting ways to make these measurements using a unit called "parts per million."* Display **slide C**, which contains a data table in percent and parts per million.

Give students time to turn and talk. Using the prompt on **slide C**, give students one minute to turn and talk about their ideas before facilitating a whole-group discussion.

Suggested prompts	Sample student responses
One way that scientists measure gases is in "parts per million." What do you think "parts per million" means?	*Each part is a molecule, so if you look at a million molecules, how many of them will be a different gas?* *Out of a million total gas particles, a certain amount of them are carbon dioxide, nitrogen, and so on.*
What if, instead of one million parts, there were two million parts? Ten million?	*There will be twice as many carbon dioxide particles.*

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICAL AND COMPUTATIONAL THINKING

Use the plastic bag as a visual to engage in ratio reasoning. Support students in discussing how to measure a particular gas in a given air sample. For a sample of one million gas molecules, on average 780,000 of 1,000,000 will be nitrogen molecules and only 410-411 will be carbon dioxide. Use this difference to emphasize how abundant some gases are in the atmosphere, while other gases seem somewhat insignificant. Calculating percents from parts per million is a secondary skill compared to being able to understand the mathematical meaning of the value of "parts per million" and use of this unit to draw a conclusion about the quantities of different gases in the atmosphere.

Use the plastic bag to demonstrate sampling air. Open the bag wide to fill with air and then seal the bag so that it's partially inflated. Say, *This bag has a sample of air molecules in it. Let's imagine that there are one million air molecules in it, though there are actually many, many more! If we had a million air molecules in the bag, how many do we think would be nitrogen, according to our data here?* Use the bag to help facilitate an understanding that, for every million molecules, a certain portion of them will be each kind of gas.✱

Practice representing parts per million as a fraction and percent. Using the data table, have students work in partners to practice moving between parts per million and percent. Ask partners to pick one gas from the table to write as a fraction in their notebook or on scrap paper.

Suggested prompt	Sample student response
How could we write parts per million as a fraction?	*For example, carbon dioxide is 411 ppm. 411 ppm as a fraction is 411/1,000,000.*

Say, *We just figured out that parts per million or ppm can be written as a fraction. Some graphs show percentages instead of ppm. How does the data showing ppm compare to data representations showing percents? Let's figure that out. Discuss with your partner how to turn the fraction into a percent. You don't have to do it. Just explain to your partner how you would convert these fractions into a percent.*

Bring students back together and check that they have an understanding that percent and parts per million are different ways of accounting for quantities and concentrations of gases in the atmosphere. Practice conversions together on the whiteboard or chart paper as needed.

Say, *Now we're ready to see if anything is changing in the atmosphere. Seems like nitrogen and oxygen are pretty important gases for our atmosphere, and most everything else is in actually quite small amounts. Let's see if anything is going on with these different gases that could be related to temperature change.*✱

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Use this opportunity to emphasize the vastly different quantities of gases in the atmosphere, in particular, carbon dioxide making up very little of the overall mixture of gases. You can help students scale their understanding of the immensity of the atmosphere by connecting to everyday processes they know change the molecules found in the air. For example, every living thing gives off carbon dioxide into the atmosphere, yet carbon dioxide remains a small overall amount of the total gases.

3 · ANALYZE CHANGES IN COMPOSITION OF GASES IN THE AIR

15 min

MATERIALS: *Concentration of Gases in the Atmosphere Over Time* handout, calculator

Recall what we're trying to figure out and the data we need to do this. Say, *Let's remind ourselves of what we're trying to figure out. Our question is: Are there any changes in the air that could be related to rising temperatures? Now that we know what is in the air, what else do we need to answer our question? In other words, what additional data do we need to see if anything is changing?*

Listen for students to suggest:

- *Data showing gases since the temperature started rising.*
- *Data showing gases over time.*
- *Data showing any change in the gases.*

Guide students to the idea that we need data that shows whether the gases are changing over time— for example, data showing the amount of each gas over a certain period of time.✱

Prepare students for data observations. Say, *Yes, we need to see if the amount of these gases are changing and, if so, by how much. We have some data for a few gases in the atmosphere. These are graphs that show the concentration of each gas in the atmosphere over a period of 100 years. We don't have data for every gas, but do have it for some of the most abundant ones, like nitrogen, oxygen, and carbon dioxide.*

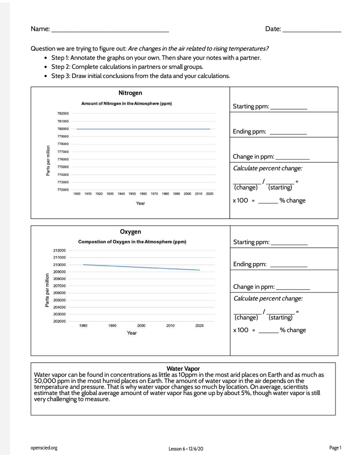
✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STABILITY AND CHANGE

When students begin their analyses of the data and calculate percent change, encourage students to use the crosscutting concept of Stability and Change as a lens for explaining what is happening to gases over time. Students should know that fluctuations within a normal range can be considered stable (Lesson 2) but that an overall trend in one direction could indicate a change in the normal pattern. Prompt students to think about whether the data supports a stable pattern or a changing pattern.

Pass out 1 copy of the *Concentration of Gases in the Atmosphere Over Time* handout to each student. Use **slide D** to give students direction for working with a partner on their analyses. Get students started on step 1.

- Individually, students will annotate their handout with noticings, writing their ideas onto the graphs. They can also document wonderings.
- With a partner, students will discuss their noticings and add additional notes.
- Students should notice that the labels of the axes are parts per million (*y*-axis) and years (*x*-axis). They should also notice that the scales on both axes are different for each graph because their concentrations differ and the time period differs slightly. For example, data for oxygen is only given from 1980 until 2020.
- They should also see that there is no graph for water vapor and that the information is given in text format.

Before students begin step 2 to make calculations, bring the students back together for a whole-group check-in about their noticings.



Name: ______________ Date: ______________

Question we are trying to figure out: *Are changes in the air related to rising temperatures?*

- Step 1: Annotate the graphs on your own. Then share your notes with a partner.
- Step 2: Complete calculations in partners or small groups.
- Step 3: Draw initial conclusions from the data and your calculations.

Starting ppm: ______
Ending ppm: ______
Change in ppm: ______
Calculate percent change:
______ / ______ = (change) (starting)
x 100 = ______ % change

Water Vapor
Water vapor can be found in concentrations as little as 10ppm in the most arid places on Earth and as much as 50,000 ppm in the most humid places on Earth. The amount of water vapor in the air depends on the temperature and pressure. That is why water vapor changes so much by location. On average, scientists estimate that the global average amount of water vapor has gone up by about 5%, though water vapor is still very challenging to measure.

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Suggested prompts	Sample student responses	Follow-up questions
What do you notice about the concentration of the gases over time?	*Some gases are changing a lot more than other gases.*	*How did you determine that?*
Did anyone notice the data given for oxygen. How is that graph different from the other graphs?	*There is no data before 1980 recorded on the graph.*	*Why do you think that is the case?*
What is different about water vapor?	*There isn't a graph. It's really hard to measure and changes so much from place to place.*	*What did we already learn about water vapor in the atmosphere?*

Say, *Now we need to see how much the gases have changed over time and if the changes are big or small. To do this, we will calculate the percent change of each gas in the air over time.*

Prepare students to find the percent change to complete step 2 on their handout. Display **slide E** with an example calculation to complete together.

- Subtract to find the change (Ending ppm-Starting ppm).
- Divide the change by the starting ppm.
- Then multiply by 100.
- Ex: (360-300)/300 = 0.20 x 100 = 20% change.

Students calculate the percent change. Display **slide D** again and direct students to complete steps 2 and 3 on their handout with a partner or small group. Provide each group with a calculator. Water vapor is given to students (5%). When the students get to step 3, suggest that students use +/-/= to show increasing, decreasing, or staying the same.

4 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION AND ADD TO DQB

15 min

MATERIALS: science notebook, sticky notes, markers, whiteboard or chart paper, DQB, Model Ideas list

Discuss and categorize the gases by how much they have changed. Gather in a Scientist Circle with the DQB visible. Display **slide F**. Work as a class to categorize the gases by which ones are changing the most and which are changing the least based on the percent change.✱

Create a chart with the headings shown below. Decide on how to agree on what constitutes a change versus what is stable over time. Then work together to agree upon which gases belong in each column.

Not really changing	Changing a little	Changing a lot
Nitrogen *Oxygen*	*Water vapor*	*Carbon dioxide* *Methane*

Add to the Model Ideas list. Start a new model ideas list or continue to add to your existing chart from lesson set 1. With your class, co-construct summary ideas from this lesson to add to your class chart. Example ideas may include:

- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.
- Students may want to add an idea similar to, "The atmosphere is made from different concentrations of gases", which is also fine.

Model Ideas List

- Some gases have not really changed over time, but some show an unusual increase.
- Carbon dioxide and methane are a small percent of the atmosphere but are increasing at a high rate.

KEY IDEAS

Purpose of the discussion: to identify that a few gases in the atmosphere are changing over time.

What to look/listen for:

- students to identify that nitrogen and oxygen are mostly stable and not changing over time,
- students to identify that carbon dioxide and methane are increasing by a high percentage,
- students to classify water vapor as "changing a little", and
- students to conclude that, while carbon dioxide and methane make up a small quantity of gas in the atmosphere, the change over time for both types of gas is unusually high.

ASSESSMENT OPPORTUNITY

Building towards: 6.A Apply mathematical concepts of ratio and percent to understand the quantity of and stability and/or change in the concentration of gases in the atmosphere over time.

What to look/listen for: See Key Ideas above.

What to do: If students struggle to draw conclusions, do the following. Draw a two-column chart. Label the left column "Abundance in the atmosphere" and the right column "Percent change over time." In the left column, have students list the gases from most to least abundant (i.e., nitrogen, oxygen, water vapor, carbon dioxide, and methane). In the right column, have students list the gases from greatest to least change over time (i.e., methane, carbon dioxide, water vapor, oxygen, and nitrogen). This should help students see that the most abundant gases are the most stable, while gases in smaller quantities are changing the most over time.

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

As students share their conclusions about the stability or change in gases over time, encourage them to use both scale and quantity thinking, as well as stability and change thinking to support their conclusions. They can reference their calculations for percent change to support their conclusions, too. One of the most perplexing ideas that should emerge through this work is that the most abundant gases in the atmosphere are stable, while the gases in smaller quantities are changing at an unusually high rate. This should prompt questions from students about whether gases in such low abundance matter enough to affect temperatures.

Problematize what we have figured out. Say, *We see that methane and carbon dioxide are increasing the most. But so what? How could gases that are so small in amount in the atmosphere really matter? And it seems really strange that carbon dioxide , the gas we exhale and that plants use to make food could be related to temperature change anyway? Now that we do know some gases are changing in the atmosphere, this may prompt new questions for you. Look back at any wonderings you had today, or even previously, and let's see if we can get new questions on our DQB that we need to answer now.*

Display **slide G**. Give students sticky notes and a few minutes to record new questions they have.

Add new questions to the DQB. Facilitate students in adding and categorizing those questions on the DQB. Just as with the original DQB, ask students to read their questions one at a time and make connections to other students' questions. Categorize the questions and add labels to the categories.

Questions that could come up for discussion (add to DQB):

- Pollution-related questions: Is it pollution? Are carbon dioxide and methane bad gases and/or if these are gases that are part of the "normal" composition of air, then is the rise in carbon dioxide bad? We know from previous lessons that plants need carbon dioxide to make food.
- Methane-related questions: What about methane? Is it needed?
- Crosscutting concept-related questions: How could a gas that is only a *small fraction* of the air in the atmosphere *cause* temperatures to rise? Is it causing temperatures to rise? (Focus is on deciphering causation version correlation.)

5 · NAVIGATION

3 min

MATERIALS: None

Summarize what we have figured out. Tell students that we have figured out that carbon dioxide and methane in the atmosphere are both rising at an unusually high rate compared to the other main gases that are staying mostly the same or slightly changing. Say, *We are wondering if gases that are rising are related to the temperatures going up? Right now we only see that they could be related (correlated), but we'd need more information to understand if carbon dioxide and methane are causing a temperature change. It's really strange that gases that we can't even see with our eyes, and ones that are in such a small amount overall, could possibly be causing these unusual changes on Earth. Any ideas about how these gases could cause this to happen?*

Listen for students to suggest:

- They trap heat.
- They absorb sunlight.
- They act like a blanket.
- They have something to do with the greenhouse effect.
- They are bad for our environment.

Additional Lesson 6 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	**CCSS.Math.Content.6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.** Through discussion and calculations, students apply grade-appropriate mathematical concepts related to ratio reasoning to describe and explain measurement of and change in atmospheric gases. For example, students parse descriptions of quantities that use rate language (like “parts per million”) and practice converting parts per million to fractions and percentage. To better understand change in gas concentration, students calculate a “percent change” over a time period of 100 years. In each case, the ratio reasoning supports students in making sense of how amount and change over time can communicate very different things about what is happening to gases in the atmosphere. For example, looking at amount alone may mislead someone to conclude that carbon dioxide is insignificant, while calculating percent change would lead to a different conclusion. If students need extra support with ratio reasoning or representations, consider offering math supports, like targeted questioning or anchor charts on ratio language or graphing on the coordinate plane, so that students can demonstrate their understanding of key science concepts through mathematical language and representations. Support may focus on helping students to identify ratio language like “per” or two quantities separated by the word “to” and translating these ratios to make sense of how one quantity is compared to another (for example, making sense of “carbon dioxide molecules per million gas molecules” to mean how many carbon dioxide can be found in a sample of one million particles).