A Degree of Change

Exploring Global Climate Change

OVERVIEW	
Unit Title:	**Length of Lesson in # of Hours:** 3–5 **# of Classes:**
How does this lesson connect to previous or future work as exemplified by the Standards in your scope and sequence? This can be a stand-alone lesson or fit into other units, connecting to various topics and math skills and concepts.	

LESSON OBJECTIVES

At the end of this lesson, students will be able to:

- Informally reason about temperature scales and global average temperature
- Describe the causes and impacts of increases in global average temperature
- Analyze graphs about the causes and impacts of climate change
- Facilitate a slow reveal graph routine for their peers

STANDARDS	
Citation	
4.MD.2	Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. **Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.**
6.SP.5c	Summarize numerical data sets in relation to their context, such as by: c. Giving quantitative measures of center (median and/or **mean**) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered. *(In this lesson, students reason visually and informally about the arithmetic mean and how it is affected by changes in the data.)*
ELA R7 D	*CCRSAE Reading 7D; adapt for other levels* Integrate information presented in different media or formats (e.g., in charts, graphs, photographs, videos, or maps) as well as in words to develop a coherent understanding of a topic or issue.

ELA S&L 4	*CCRSAE Speaking & Listening Anchor 4; adapt to the level of your students* Present information, findings, and supporting evidence such that listeners can follow the line of reasoning.
NGSS *ESS2.D*	*NGSS Disciplinary Core Idea: ESS2.D: Weather and Climate* • Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time. • Climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years. • Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise.
NGSS *ESS3.D*	*NGSS Disciplinary Core Idea: ESS3.D: Global Climate Change* • Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming).
NGSS	*NGSS Science & Engineering Practice: Analyzing and Interpreting Data* Choose a version of the standard depending on the level of your students.

1 - 3 MATHEMATICAL PRACTICE(S) ADDRESSED IN THIS LESSON	**ELEMENTS OF RIGOR**
MP.3 Construct viable arguments and critique the reasoning of others MP.4 Model with mathematics MP.6 Attend to precision	*Which aspect(s) of Rigor do the targeted Standard(s) require?* ☒ Conceptual understanding of key concepts ☐ Procedural skill and fluency ☒ Rigorous application of mathematics in real-world contexts

ESSENTIAL QUESTIONS

Why is it significant if the global average temperature increases by one or two degrees?

Why is the global average temperature increasing?

What are the impacts of climate change?

Who is impacted by climate change?

EVIDENCE OF LEARNING
Ways I and my students will know the extent to which the objectives have been met.
Students will facilitate a slow-reveal graph about climate change for their peers and reason about the significance of the global average temperature increasing by one or two degrees.

LEARNING PLAN - Vocabulary
Climate Weather Degree Fahrenheit Celsius Average Atmosphere Emissions Climate model

LEARNING PLAN - Introduction	MATERIALS	TIME
1. Open the class with a discussion about the weather. What is the temperature outside today? Is it warm or cold? How does it compare to yesterday? 2. Ask students what temperature they like best. How big is the range? For example, a student might say they like a day that is between 70 and 75 degrees, but outside of that it feels too cold or too hot. 3. Ask students how big a change in temperature they would consider a big change. For example, would the temperature going up by 5 degrees be enough to make them take off their jacket? Would the temperature going down by 10 degrees be enough to make them turn up the heat in their homes? 4. Ask students if they think an increase in temperature of one degree is significant. Why or why not?		

Note to teacher: *These are subjective questions and there is no right or wrong answer. The idea of this discussion is to get students thinking about temperature and what kinds of changes in temperature they consider significant.* **Segue:** Say that today we're going to talk about climate change and what is going on with the global average temperature.		
LEARNING PLAN – Body of the Lesson	**MATERIALS**	**TIME**
Measuring Temperature		
1. Do the Desmos activity *Measuring Temperature*. You can find a complete teacher guide to the activity *here*. Facilitate a class learning experience, moving students through the activities as a group, sharing selected responses and prompting discussion. ***Note to teacher:*** *For guidance on Desmos, visit the Desmos Classroom help page. You will find guidance on using Desmos classroom activities and on integrating Desmos with Google Classroom. The SABES Mathematics and Adult Numeracy Curriculum & Instruction PD Center also offers support with Desmos in the form of workshops and individual coaching.* ***Note to teacher:*** *For settings where computer and internet access is not available, the teacher can print out the teacher guide to the activity and adapt it to a no-technology setting by giving students the handout Thermometer and conducting the activity with students using it as reference.* 2. Key takeaways (bring these up if they don't arise from the class): • There are two scales that people use for measuring temperature. They appear quite different and different numbers connote hot or cold in each scale. • Students who come from outside the U.S. will likely be more used to the Celsius scale and may be unfamiliar with Fahrenheit. • Degrees Celsius are *bigger* than degrees Fahrenheit. What does this mean for thinking about changes in temperature? [A change of a couple of degrees Celsius is a bigger change than a change of a couple of degrees Fahrenheit.]	Desmos activity: *Measuring Temperature* *https://teacher.desmos.com/activitybuilder/custom/6433492a7c88d1275941ce95* Desmos teacher guide: *Measuring Temperature* *https://teacher.desmos.com/activitybuilder/teacherguide/6433492a7c88d1275941ce95* Desmos Classroom help page: *https://my.amplify.com/help/en/collections/3777043-desmos-classroom* Computers, tablets, or phones with internet access (computers or tablets preferred). HO: *Thermometer* (only needed if not using computers)	

Average Temperatures and Global Average Temperature		
3. Do the Desmos activity *Average Temperature*. You can find a complete teacher guide to the activity *here*. Facilitate a class learning experience, moving students through the activities as a group, sharing selected responses and prompting discussion. ***Note to teacher:*** *This activity requires a computer with internet access, but it can be facilitated with one computer projected to a screen if necessary. Either invite students to come up and manipulate the sliders or have them tell you how to manipulate them. Have class discussions instead of having students address the prompts in the activity.* ***Note to teacher:*** *If no computers are available, adapt the activity to a no-technology setting using the teacher guide to the activity and the handouts Average Temperatures and Average Temperatures Part 2 to substitute for the screens where students look at and manipulate thermometers.* 4. Key takeaways: • A change in the average reflects greater changes in the individual data points. • Different scenarios can produce the same average or the same change in average. • Knowing only the average masks details about what is going on in specific locations. • The global average temperature is rising, but that doesn't mean that it is rising uniformly everywhere. • Thinking about means (averages) visually builds more conceptual understanding and connection to context than carrying out a procedure.	Desmos activity: *Average Temperature* https://teacher.desmos.com/activitybuilder/custom/64339d16cdb943e8b4cd30c4 Desmos teacher guide: *Average Temperature* https://teacher.desmos.com/activitybuilder/teacherguide/64339d16cdb943e8b4cd30c4 Computers, tablets, or phones with internet access (computers or tablets preferred). HOs: *Average Temperatures* and *Average Temperatures Part 2* (only needed if not using computers). HO: *Average Temperatures—Answer Key*	
Why is the Average Global Temperature increasing?		
5. Now that we have an idea of what is meant by global average temperature. We also know changes in global average temperature are often described in degrees Celsius, which are bigger than the degrees Fahrenheit that are familiar to those of us who grew up in the U.S. Now let's visit the second question: *Why* is the global average temperature increasing? 6. Show slides or pictures: one of the Moon's surface, one of the earth's surface. Ask students to guess the hottest and coldest surface temperatures for each. 7. Reality: a. "Daytime temperatures near the lunar equator reach a boiling 250 degrees Fahrenheit (120° C), while nighttime temperatures get to a chilly -208 degrees Fahrenheit (-130° C).	Pictures of the Moon's surface and Earth's surface. For examples, see https://moon.nasa.gov/resources/484/apollo-17-landing-site-the-taurus-littrow-valley/ https://www.nasa.gov/topics/earth/images/index.html	

The Moon's poles are even colder." Source: NASA (*https://lunar.gsfc.nasa.gov/images/lithos/LROlitho7temperaturevariation27May2014.pdf*) b. "The highest temperature ever recorded on Earth was 136 Fahrenheit (58 Celsius) in the Libyan desert. The coldest temperature ever measured was -126 Fahrenheit (-88 Celsius) at Vostok Station in Antarctica." Source: *https://coolcosmos.ipac.caltech.edu/ask/63-What-are-the-highest-and-lowest-temperatures-on-Earth-*		
8. Note that it gets both much colder and much hotter on the moon than on earth even though both are about the same distance from the sun. So, what is the main difference? The earth has an **atmosphere** and the moon does not. 9. Ask, a. What would Earth be like without the heat-trapping effect of the atmosphere? **(like the moon)** b. What would Earth be like if the heat trapping effect of the atmosphere increases? **(hotter!)** c. WHY is our heat-trapping blanket getting thicker? **(Is the atmosphere actually getting thicker? No…)**		
10. Show *The Physics of the Greenhouse Effect* video from PBS Learning Media (the website includes the video along with an essay for teacher background knowledge, and suggested discussion questions), that describes how the atmosphere helps the earth be warm enough for us to live on it, but also how adding CO_2 to the atmosphere is causing it to trap more heat and that this is a trend. Use the discussion questions provided on the website. More background for the teacher is available in the following document: *https://www.ipcc.ch/site/assets/uploads/2018/03/ar4-wg1-chapter1.pdf*, (see p. 115) The document above, along with other related resources can be found at: *https://www.ipcc.ch/report/ar4/wg1/historical-overview-of-climate-change-science/*	Video: *The Physics of the Greenhouse Effect* (2 min 15 sec), with background knowledge essay and discussion questions *https://mass.pbslearningmedia.org/resource/phy03.sci.phys.matter.greenhouse2/global-warming-the-physics-of-the-greenhouse-effect/*	
Climate and Weather		
11. Show the video *The Difference Between Climate and Weather* on data trends vs. variations of data points. This video establishes the terms **weather** and **climate** at the very end using this analogy: "The owner is the climate; the dog is the weather."	Video: *The Difference Between Climate and Weather* (1 min 4 sec) *https://youtu.be/ePL-uOg9hSU*	

12. Say: Now that we've heard the terms weather and climate, • What do you think these terms mean? • What is the difference between weather and climate? • How are they related?		
Note to teacher: *Here are some optional slides on how latitude and altitude contribute to changes of temperature patterns, leading to different climates.*	PPT: *Climate, Weather, Altitude and Latitude* slides (optional)	
13. Sort a few weather and climate statements to solidify the idea of **trends over time versus occasional ups and downs**. There are two options for the sort: 1) a *Desmos activity* that students can do in a facilitated class, or 2) the teacher can share the screen and ask participants to talk through which one to put where, and why. Page 2 of the activity asks users to choose one of the four statements about weather and climate that makes sense to them and explain why. Page 3 asks users to add their own statement. Share responses and discuss. ***Note to teacher:*** *If no computers are available, adapt the activity to a no-technology setting using the handouts Weather & Climate Card Sort and Describing Weather & Climate. Print and cut apart the card sort for students to sort manually. Print the weather and climate statements for students to consider and reflect on.* ***Note to teacher:*** *Below are some additional weather and climate sorts.* • *https://wordwall.net/resource/29539090/weather-and-climate-sort* • *https://www.watershedcouncil.org/uploads/7/2/5/1/7251350/climate_curriculum-lesson2-2-1-2017.pdf* ***Note to teacher:*** *Below are some optional background information / potential articles for students to read about weather and climate. You can find even more options on the Resource list.* • *https://oceanservice.noaa.gov/facts/weather_climate.html* • *https://climatekids.nasa.gov/weather-climate/* • *https://www.bbc.com/news/science-environment-24021772*	Desmos activity: *Weather & Climate Sort* *https://teacher.desmos.com/activitybuilder/custom/64501fcfa369c72dd07a9b77* Desmos teacher guide: *Weather & Climate Sort* *https://teacher.desmos.com/activitybuilder/teacherguide/64501fcfa369c72dd07a9b77* HO: *Weather & Climate Card Sort* HO: *Describing Weather & Climate* (only needed if no access to computers)	
Slow Reveal Graphs – Teacher Led		
14. Conduct a slow-reveal graph with the graph *Global Average Temperature*. When it becomes clear that the graph is about global average temperature, make space in the discussion for	PPT: *Global Average Temperature* Projector or shared screen	

student ideas and questions about the meaning of global average temperature and how it is measured. ***Note to teacher:*** *For information and guidance about conducting a slow reveal graph, see What IS a #slowrevealgraph?* *Some questions to ask on most slides:* • *What do you notice?* • *What do you wonder?* • *What guesses do you have about what this graph is about?* *Some questions you might want to ask nearer to the end:* • *What are your takeaways?* • *What new questions do you have?* • *How do you feel?* • *What will you do?* • *What do you like or not like about this kind of data representation?* • *Why do you think the creators of this representation chose to show it this way?* • *How would you represent this data?*	*What IS a #slowrevealgraph? https://slowrevealgraphs.com/2018/12/04/the-journey-begins/*	
15. Conduct a slow-reveal graph with the graph *Future Warming Pathways*. As the meaning of the graph becomes clear, lean into the questions of "How do you feel?" and "What will you do?" ***Note to teacher:*** *The idea here is not to communicate to students that solving climate change is their responsibility, but simply to ask what they will do now that they have this information – it might be that they will learn more, change their habits, take political action, console themselves with comfort food, or do nothing – all are legitimate responses.)*	PPT: *Future Warming Pathways*	
Slow-Reveal Graphs – Student Led		
16. Tell students they will work with a group to analyze a slow-reveal graph about climate change and then present it to the class, revealing it one step at a time and facilitating discussion as you just did with the previous two graphs.		

17. Display the grid of *slow-reveal graph thumbnail images*. Give students a few minutes to look at the graph images and decide which ones intrigue them. 18. Create student groups (2–4 students in each group) based on the graphs students choose. (Students can name the graphs using the letters and numbers on the sides of the grid, for example, graph 2A or graph 1D.) 19. Give each group the link for the graph they have chosen. Student groups should go through the slow-reveal process on their own, taking time to discuss each slide as they look at it. Give them the handout *Facilitating a Slow-Reveal Graph* to support their work. ***Note to teacher:*** *For some more background information and detail on the student graphs, including relevant vocabulary, see the document Slow Reveal Graphs— Vocabulary and Resources.* ***Note to teacher:*** *In a setting where students cannot access computers or the internet, you may choose several slow-reveal graphs to print out and give to student groups (one slow-reveal graph per group). Print one slide per page.*	PPT: *Slow Reveal Thumbnails slide* *Student-Led Slow Reveal Graphs collection* Laptops or tablets with internet access HO: *Facilitating a Slow-Reveal Graph* Background information for teachers: *Slow Reveal Graphs— Vocabulary and Resources*	
20. Have student groups present their graphs to the whole class, facilitating them as slow-reveals. 21. At this point, students will have looked at a collection of graphs on different topics connected to climate change and will be building a more complete picture and hopefully generating more questions they want to investigate. Ask students to tell the story of climate change based on what they have seen so far. In other words, what is the story that the class has told collectively?		
LEARNING PLAN – Closure / Conclusion	**MATERIALS**	**TIME**
Formative Assessment: Closing Discussion and Exit Ticket Discuss and then write answers to these questions: (1) Describe 2–3 things you learned about global average temperature. (2) Give 1–2 examples of what and/or who are impacted by climate change. (3) Based on what you've learned in this lesson, what do you think is causing the global average temperature to increase? (4) Based on your team's slow reveal graph or one presented by your peers, provide an example of how the data or information helped you better understand something new you learned about climate change. Please share why that is important to you.		

EXTENSIONS	MATERIALS
Extension: Earth Temperature Timeline Share this *xkcd cartoon* with students. This cartoon shows the changes in the global average temperature going back to the year 20,000 BCE. Have students take their time scrolling through it, sharing their impressions along the way. **Extension: Climate Heroes** Students research and report on climate heroes. **Extension: Climate Regional Response** Students research and report on the impacts of climate change and how people are responding in a region of their choice. **Extension: Where is the CO_2 coming from in Earth's atmosphere?** 1. See what students know and put sources in two categories: regular CO_2 and rampant CO_2. **Regular:** Plant and Animal Respiration; Ocean; Volcanoes; Fires **Rampant:** Burning fossil fuels (wood, coal, oil, natural gas); Removing natural "sinks" (deforestation) 2. Follow the directions for *Our Changing Atmosphere* from the Exploratorium: *https://www.exploratorium.edu/sites/default/files/stem/OurChangingAtmosphere.pdf* There may only be two groups, so have students do the data from 2006 and 2017. After students have created the graphs, put them on the board. What is going on here? Discuss how the seasonal cycles are related to normal CO_2. What do they notice about the two graphs? They should note that although both show the same seasonal variation, the amounts for 2017 are all higher. 3. Show the video about the Keeling Curve from the American Museum of Natural History: *https://www.amnh.org/explore/videos/earth-and-climate/keeling-s-curve-the-story-of-co2* Have a student volunteer to read the captions. Discuss how the rise in average CO_2 is due to "rampant CO_2" from human activities. **Extension: Story-articles from the NOAA National Centers for Environmental Information** • *In Harm's Way: Hurricane Ida's Impact On Socially Vulnerable Communities* • *In Hot Water: Ocean Heat and Our Warming World*	Computers, tablets, or phones with internet access

Extension: Science Snacks

Science Snacks are low-cost, teacher-tested activities developed by The Exploratorium. Some to consider:

- *Melting Ice and Rising Seas* – Melting ice is a major factor contributing to sea level rise. This happens due to warming air temperature. Does the location of melting ice on Earth affect the way sea level rise occurs? Investigate with this model of seas and continents. *https://www.exploratorium.edu/snacks/melting-ice-rising-seas*
- *Swelling Seas* – One of the main causes of sea level rise is the warming of our oceans. In this Science Snack, you'll see for yourself the effect of temperature change on water. *https://www.exploratorium.edu/snacks/swelling-seas*

Extension: EMPower™ Activities

If using the EMPower math series, *Many Points Make a Point, Lesson 7* is about Averages (Mean), and *Lesson 8* is about some Climate Graphs.

Extension: Temperature Conversion

The *Digital Literacy with Spreadsheets: A Math Packet for Adding Spreadsheets to Your Math Teaching Toolbox* collection includes an *Investigating Temperature Conversions & Linear Functions* lesson: *https://www.dropbox.com/s/u0xs4v4yc621fsf/InvestTempConversions_LinearFunctions_LessonPacket.pdf?dl=0*

Supporting and Additional Resources can be found at:
https://www.dropbox.com/sh/9yzl6zdwanp7kbb/AADymKbuMefdV2lOK85cLhvZa?dl=0