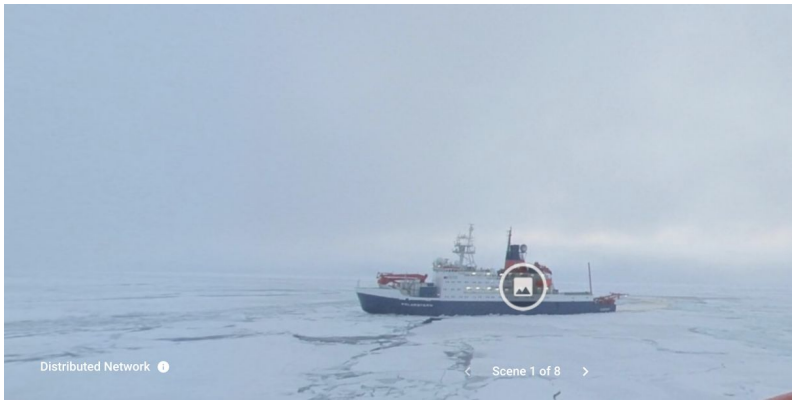
Arctic Fieldwork

Setting the Stage



The MOSAiC expedition aims to better understand the changing Arctic climate system by studying atmosphere, ice, and ocean processes. At the heart of the MOSAiC expedition is the German icebreaker, *Polarstern*, which was transformed into a drifting climate observatory frozen in the Arctic sea ice. As the icebreaker drifted with Arctic currents, scientists collected Arctic climate system data for an entire year. In this lesson, students visit MOSAiC field sites through virtual reality Google Expeditions and interact with shortwave and longwave energy datasets from the Arctic to understand how the Arctic energy budget has changed over time.

Lesson Overview

- *Part 1 – (10 minutes) Atmospheric CO_2 and Temperature*
  Students observe patterns in atmospheric CO_2 concentrations globally and relate patterns to the phenomenon.
- *Part 2 – (10 minutes) MOSAiC Expedition*
  Introduce students to the MOSAiC expedition through discussion and a short video.
- *Part 3 – (25 minutes) MOSAiC Distributed Network Google Expedition*
  Students will use VR Google Expeditions to explore MOSAiC field sites developed as part of the Distributed Network.
- *Part 4 – (25 minutes) Arctic Radiation Graphing*
  Students will plot and analyze shortwave (solar) and longwave (heat) energy datasets from the Arctic.
- *Part 5 – (10 minutes) Update Earth's energy budget model worksheet*
  Students update their "Earth's energy budget model worksheet" to include greenhouse gases and the greenhouse effect.
- *Part 6 – (10 minutes) Summary Table*
  Students reflect on their learning and how it helps them understand the unit driving question.

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Instructional Overview	
Grade Level	Middle/High School
Instructional Time	90 minutes
Standards Alignment	**NGSS Disciplinary Core Ideas:** ● **ESS2.D: Weather and Climate** **NGSS Science and Engineering Practices:** ● Analyzing and Interpreting Data **NGSS Crosscutting Concepts:** ● Energy and Matter ● Stability and Change
Unit Driving Question	● Why might the Arctic be warming twice as fast as the rest of the world?
Driving Question(s) For This Lesson	● What scientific instruments are MOSAiC scientists using to study the changing Arctic climate system? ● How has the amount of shortwave and longwave energy coming and going from the Arctic changed over time?
Learning Goals	● Identify patterns in shortwave and longwave energy over time. ● Develop scientific questions related to shortwave and longwave energy datasets.

Materials	❑ Arctic Fieldwork PPT
	❑ Arctic Fieldwork student worksheet
	❑ Answer Key
	❑ Figure Descriptions - Atmospheric CO_2 and Temperature
	❑ MOSAiC video
	❑ Computer/Ipad (1 per student)
	❑ "MOSAiC Distributed Network" Google Expedition
	❑ "Earth's energy budget model" worksheet (Students should have a copy of this worksheet as it was distributed and modified in the previous lesson)
	  ❑ Blank worksheet
	❑ Summary Table
	❑ Initial ideas public record
	❑ Radiometer datasets: In Part 4, students will graph and interpret longwave and shortwave datasets from the Arctic over the period of 2000-2018. The 3 graphing options for your classroom are listed below in order of difficulty (Option 1 the easiest, Option 3 the most challenging).
	  ❑ Option 1: Students are given graphs showing both longwave and shortwave datasets from 2000-2018.

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	❏ Option 2: Students plot both longwave and shortwave datasets during the period from 2000-2018. ❏ Option 3: Students produce line graphs in Google Sheets or Excel using the longwave and shortwave datasets provided. Optional: ❏ Latitudinal distribution of CO_2 visualization
Material Preparation	❏ Cue and test web links ❏ Print student worksheets ❏ Print graphs/datasets for students (if completing Options 1 or 2 see description above) ❏ Review presenter notes in the Arctic Fieldwork PPT ❏ Review Answer Key ❏ Display summary table and initial ideas public record.
Vocabulary	• Radiometer - instrument used to measure the amount of incoming and outgoing longwave (Earth) and shortwave (solar) radiation • Meteorological sled - A large sled mounted on teflon runners to move around the ice. Attached to the sled is a wide range of meteorological and atmospheric sensors. • Distributed Network - a series of research stations set up on ice up to 50 km away from the *Polarstern,* the central observatory of the MOSAiC expedition.

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Part 1 - Atmospheric CO_2 and Temperature (10 minutes)

Refer to Part 1 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Describe change in surface temperature and atmospheric carbon dioxide figures (see presenter notes or this pdf for figure descriptions)
2. Students answer questions requiring them to interpret change in surface temperature and change in surface atmospheric carbon dioxide figures.
3. Facilitate a discussion in which students consider whether or not atmospheric CO_2 is responsible for the amplified warming in the Arctic.

Optional Extension: Watch this Latitudinal distribution of CO_2 visualization which shows the change in atmospheric CO_2 concentration from 1981 to the present.

4. Display the graph comparing Arctic and global temperature anomalies since 2000 (see PPT). Emphasize to students that the rise in atmospheric CO_2 is causing global temperatures to increase, but we as a class still don't know why temperatures are rising so rapidly in the Arctic.

Part 2 - MOSAiC Expedition (10 minutes)

Refer to Part 2 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Introduce students to the MOSAiC expedition
    a. Say, "What happens in the Arctic doesn't stay in the Arctic. Earth's climate is an interconnected system, and the rapidly warming Arctic is affecting the climate at lower latitudes. However, climate scientists have struggled to predict how the changing Arctic climate system will impact the climate at lower latitudes in the future because we don't fully understand the ocean, atmosphere, and ice processes in the Arctic."
    b. Describe the MOSAiC expedition plan (for more information see slide #8 and review the presenter notes)

2. Watch this MOSAiC video for additional background information about MOSAiC.

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3. Before introducing students to Part 3, make sure students fully understand the role(s) of the Russian support vessel, *Fedorov*, as it relates to deploying the distributed network (*see presenter notes*). This is important because in Part 3 students will be virtually touring the *Fedorov* and joining scientists on the ice as they deploy the distributed network. Note that the *Fedorov* and *Polarstern* are two different ships, the *Polarstern* was the ship frozen into sea ice that drifted with the ice across the Arctic, the *Fedorov* deployed the distributed network (a series of research stations up to 50 km from the *Polarstern*) at the start of the expedition and then returned to Tromsø, Norway.

Part 3 - MOSAiC Distributed Network Google Expedition (25 minutes)

Refer to Part 3 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Before directing students to the "MOSAiC Distributed Network" Google Expedition, model it for the whole class. Click on the points of interest (white icons) to show students how to access information and pictures they'll use to answer questions on their worksheets. Move between scenes by clicking the arrow left or right.

2. Students view the Google Expedition referring to scene 1: "Distributed Network" and scene 3: "Arctic Fieldwork" to answer Part 3 questions.

3. Review Part 3 questions as a whole class.

Part 4 - Radiometer Data (25 minutes)

Refer to Part 4 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Students plot incoming shortwave and outgoing longwave radiation data for the Arctic over the period from 2000-2018. Choose between one of four graphing options below for your classroom based on the time and level of difficulty, Option 1 being the shortest/easiest, Option 4 being the longest/most difficult. Students will refer to the graphs they produce to answer Part 4 questions.
    a. **Option 1**: Students are given graphs showing both longwave and shortwave datasets from 2000-2018.
    b. **Option 2**: Students plot both longwave and shortwave datasets during the period from 2000-2018.
    c. **Option 3**: Students produce line graphs in Google Sheets or Excel using the longwave and shortwave datasets provided.

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2. Discuss Arctic radiation graphs and questions as a whole class (refer to the PPT for answer key graphs). Have students share questions they have about the radiation datasets. Present the discussion prompts below, but do not tell students the answer.
    a. **Discussion Prompt:**
        i. Why has the amount of outgoing longwave radiation from the Arctic increased over the past two decades?

3. Review the "Take home points" from the lesson (see PPT)

Part 5 - Update Earth's energy budget model worksheet (10 minutes)

Refer to Part 5 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Guide students through updating their "Earth's energy budget model worksheet" to include information about changes to the amount of shortwave and longwave energy coming and going from the Arctic over the past ~2 decades (2000-2018).The teacher should update the class model under a document camera (see Answer Key for example). Students may want to use colored pencils to copy the whole class model onto their worksheet.

Teacher Note: Remind students that they will refer to and update the "Earth's energy budget model worksheet" with new information/concepts at the end of each class.

Part 6 - Summary Table (10 minutes)

Refer to Part 6 slides included in the Arctic Fieldwork PPT. See PPT presenter notes for additional information.

1. Students work in groups to reflect on their learning and how it relates back to the unit driving question, "Why might the Arctic be warming twice as fast as the rest of the world?"

2. Facilitate a discussion in which students come to a consensus about what they learned and how it helps them understand the unit driving question. Ideas/concepts agreed upon by the class should be included in the summary table (see Answer Key).
    a. Students record new summary table entries onto their own summary tables.

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