

Why does the ice melt on the “Frozen Continent”? - Teacher Guide

Setting the Stage

After exploring albedo in the previous lesson, this lesson expands on more factors which lead to surface ice melt in Antarctica. Students begin with hypotheses and use different datasets to confirm or disprove their ideas about what leads to ice melt on the “frozen continent.” This lesson pairs a scientific mindset with hands-on exploration of datasets, all motivated by building a phenomenon-based exploration of Antarctica.

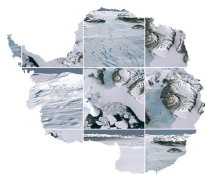


Blue ice area in front of the northernmost part of the Heimefrontfjella, East Antarctica. Credit: N. B. Karlsson via <https://blogs.equ.eu/divisions/cr/2016/01/22/image-of-week-blue-ice-in-east-antarctica/>

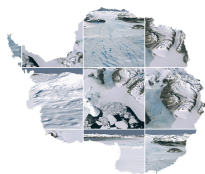
Lesson Overview

- *Part 1 – (10 minutes) Introduction*
The teacher introduces the lesson and the data which will be at the students’ disposal.
- *Part 2 – (30 minutes) Research*
Students break up into small groups to form and explore hypotheses about what causes melt in Antarctica with the available datasets.
- *Part 3 – (20 minutes) Reporting Out*
Student groups share whether they confirmed/disproved their hypotheses and why.

These materials were developed by Meghan Mosher, Penny Rodrick-Williams, Allen Pope, Anna Ruth Halberstadt, Luke Trusel, and Mahsa Moussavi in collaboration with CIRES Education & Outreach at CU Boulder. Funded by NSF OPP Award #1643715.



Instructional Overview	
Grade Level	High School
Instructional Time	60 minutes
Standards Alignment	<p>NGSS:</p> <ul style="list-style-type: none"> ● ESS2.A: Earth Materials and Systems: Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. ● Analyzing and Interpreting Data ● Using Models ● Patterns
Anchoring Phenomenon	<ul style="list-style-type: none"> ● Climate change and environmental feedback loops are causing Antarctic ice to melt, which is causing dramatic local and global impacts.
Driving Question	<ul style="list-style-type: none"> ● Why does the ice melt on the "Frozen Continent"?
Learning Goals	<ul style="list-style-type: none"> ● Students will be able to: <ul style="list-style-type: none"> ● Use a Climate Reanalyzer tool to compare melt areas in Antarctica with climatological variables. ● Build, test, and confirm or refute hypotheses using the claim, evidence, reasoning framework for an argument
Materials	<ul style="list-style-type: none"> <input type="checkbox"/> Internet-connected laptops <input type="checkbox"/> Whiteboards or Butcher Paper <input type="checkbox"/> Markers <input type="checkbox"/> Slide deck <input type="checkbox"/> Student handout
Material Preparation	<ul style="list-style-type: none"> <input type="checkbox"/> Make sure the websites are working <input type="checkbox"/> Gather enough whiteboards or butcher paper for each group <input type="checkbox"/> Print out student handouts (1 per student)
Vocabulary	<p><u>Reanalysis</u> is a scientific method for developing a comprehensive record of how weather and climate are changing over time.</p>
Instructional Strategies	<ul style="list-style-type: none"> ● Claim-Evidence-Reasoning (sometimes called Justification) structure, more information here: <ul style="list-style-type: none"> ● https://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell



	<ul style="list-style-type: none">• https://www.modelteaching.com/education-articles/writing-instruction/claim-evidence-reasoning-cer
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Web Links for Lesson Resources	
Part 1	<ul style="list-style-type: none">• Here is a quick video introducing reanalysis: https://www.youtube.com/watch?v=FAGobvUGI24• www.Climatereanalyzer.org
Part 2	<ul style="list-style-type: none">• https://climatereanalyzer.org/• https://www.climate.gov/teaching/resources/climate-reanalyzer
Part 3	<ul style="list-style-type: none">• Link to PDF scaffolding CER writing

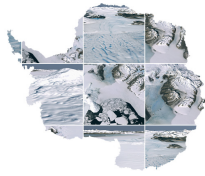
Part 1

Introduction (10 minutes)

Why does the ice melt on the “Frozen Continent”?

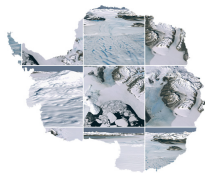
Albedo is an important driver of snow and ice melt in Antarctica. However, it is not the only thing causing surface melting on the “frozen” continent on Antarctica! In this lesson, students will use real climate data to investigate multiple hypotheses for what contributes to surface melt in Antarctica.

1. Ask students where they think melt happens in Antarctica. After soliciting a few answers, show them slide 1 in the Lesson 4 Slide Deck (also in their student handout) showing a melt map of Antarctica and explain that melt actually happens all over Antarctica, mostly around its perimeter (but not all the time!). *Note: There is a blown-up version of the map on slide 2.* Supraglacial lakes are a good place to start - lakes need to have melt around to be filled up, but they also require a certain topography and an impermeable basin to fill.
2. Move to slide 3 in the slide deck, which shows a map with Antarctic annual temperatures (again, also in the student handout). Ask students what they observe, and challenge them to connect what they see in this map to the previous map showing melt. The goal is to guide students to the question: How do you get water to melt in a place that is often below freezing?
3. Explain that you are going to study this question, using some real data. The type of data you are going to be using is called “reanalysis.” If you like, you can show students this quick video introducing reanalysis: <https://www.youtube.com/watch?v=FAGobvUGI24> You can also decide if you want to also provide this definition to students:



“Reanalysis is a scientific method for developing a comprehensive record of how weather and climate are changing over time. In it, observations and a numerical model that simulates one or more aspects of the Earth system are combined objectively to generate a synthesized estimate of the state of the system. A reanalysis typically extends over several decades or longer and covers the entire globe from Earth's surface to well above the stratosphere. Reanalysis products are used extensively in climate research and services, including for monitoring and comparing current climate conditions with those of the past, identifying the causes of climate variations and change, and preparing climate predictions.” (from Reanalysis.org)

4. Turn & Talk: Ask students to redefine reanalysis using their own words, then write their definition in the box on their handout.
5. Finally, explain to students that while reanalysis data are spatially and temporally continuous, they are at low spatial resolution (due to physical and computational limitations). As such, we will be looking regionally and at much coarser scale than the satellite imagery we have been using in previous lessons.



Part 2

Research (30 minutes)

Why does the ice melt on the “Frozen Continent”?

We know that albedo is important in driving melt. In this section, students will investigate data and make an argument about where melt is occurring and what other processes might be driving melt.

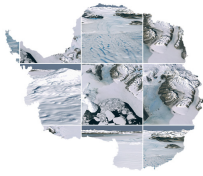
1. Divide students into groups of 3. Each student in the group will be responsible for **two** of the following variables:
 - 2m Temperature (important for melt)
 - 2m Max Temperature (important for melt - could be combined with 2m Temperature)
 - 10m Wind Speed (important for melt - but low data resolution)
 - Total Cloud Cover (not really important for melt)
 - Precipitation (not really important for melt)
 - Precipitable Water (not really important for melt - could be combined with Precipitation)
2. Explain to students that they will use a climate reanalyzer to plot their assigned variables on a map of Antarctica. They will then compare the maps of their variables with the map of Antarctic melt (shown on slide 2 and also in the student handout). The goal is to see which variables correlate with higher melt, and which do not.
3. Instruct students to create a hypothesis about whether their variable(s) are linked with melt in Antarctica before they run their analyses.
4. Using the map of melt in Antarctica shown on slide 2, choose 2-4 regions of melt and 2-4 regions of low/no melt to compare/contrast against each other. These can either be assigned or left to the students to select. Areas you might suggest/assign are:

Melt Areas

- Antarctic Peninsula / Larsen C (b)
- Antarctic Peninsula / George IV (a)
- Transantarctic Mountains (h-j)
- Dronning Maud Land Coast (c-d)
- Amery Ice Shelf (e)
- Shackleton Ice Shelf (f)

Low/No Melt Areas

- Central West Antarctica
- Inland from coastal Dronning Maud Land (c-d)
- Inland from Amery Ice Shelf (e)
- Central East Antarctica
- South Pole
- Inland from Nansen Ice Shelf (g)

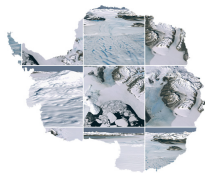


5. Explain and/or demonstrate to students how to use the climate reanalyzer tool to run their analyses:

- 1) Go to <https://climatereanalyzer.org/>
- 2) Click on Monthly Reanalysis Maps
- 3) Choose Region: Antarctic and click "Plot"
- 4) Choose the Variable you will be exploring and click "Plot"

Things to remember and consider in guiding data collection / analysis:

- Always take a note of the units and color scale.
- From the images in Lesson 1, we know melt occurs most in the austral summer (months "DJF" for December / January / February), and often peaks in January. So, we expect to focus our inquiry in those months. You can choose how wide (or narrow) a time window to look at and across how many years (by varying start year and single/multiple).
- Each time you change parameters, you need to click "plot" again.
- You can click on the plot to get an image of it which you can zoom in on.
- You can play with the dataset: Which model is used to create the reanalysis. (NCEP/NCAR is the US one, ECMWF is the European one, and there are even models that go into the future.)
- Look which areas have melt and compare those areas (and the low/no melt areas) on the plots of the variables. What similarities / differences are there?



Part 3

Reporting Out (20 minutes)

Why does the ice melt on the “Frozen Continent”?

Option 1: 20 minutes

Creating an Argument - Individual Student Option

Instruct students to use the Claim - Evidence - Reasoning format to answer the Guiding Question: *Why does the ice melt on the “Frozen Continent”?*

Question: *Why does the ice melt on the “Frozen Continent”?*

[Link to PDF scaffolding CER writing.](#)

OR

Option 2: If you have a longer time slot (e.g. 90 min):

Group Whiteboard and Argumentation Session Option

Make a Claim/Argument: Once students have conducted research and compiled data, they will revisit their initial hypothesis and make a claim about what is causing ice to melt on Antarctica.

They need to decide which pieces of evidence support their claim and justify the evidence by explaining how it supports their conclusions and connects back to what they know about the science topics covered in the last several lessons.

Making the Whiteboard: Use the following template to help students create their whiteboard (can also be done digitally or on poster or butcher paper). Suggest they make a rough draft first on a piece of printer paper:

Argumentation Session

Instructions:

- Once all the tables have designed and set up their whiteboards, students will do a round-robin session so they can see what other groups have come up with.
- Instruct students to take notes from the other tables by listening to their presentation and asking them the questions from the [Argumentation Session Questions sheet](#).

ADI ARGUMENT PRESENTATION ON A WHITEBOARD

The Guiding Question:

Our Claim: Your answer to the guiding question.

Our Evidence:

ANALYSIS

Amount

A B

Make a graph or figure to show a relationship, a change over time, or a difference between groups.

INTERPRETATION

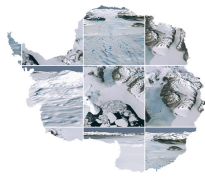
- This graph suggests...
- This graph shows...

Explain what the analysis means.

Our Justification of the Evidence:

- These are the science concepts that are important for understanding our evidence...
- Our evidence is based on the following assumptions...

Explain why the evidence matters.



- Once students have rotated through all the other groups (or when your allotted time has expired), have students return to their group and discuss what they found out from the other groups.
- Have students rework their claims if they found compelling evidence from the other groups to change their mind.

Optional Assessment: Report

Once students have completed their research, ask them to prepare an investigation report that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Their report should answer these questions in two pages or less. The report should be typed, and any diagrams, figures, or tables should be embedded into the document. Remind students to write in a persuasive style, as they are trying to convince others that their claim is acceptable or valid!

Extensions

- If you want to look at temporal variability, too - your students could look for evidence in time-series of weather station data. For example, this paper shows how melt event can occur even in the Antarctic winter:
<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL077899>;
<https://amrc.ssec.wisc.edu/aws/index.html>
- The Climate Literacy Essential Principles may be useful in unit development (e.g., albedo is part of CLEP 1):
https://cleanet.org/clean/literacy/principle_1.html
- If your students really like the satellite imagery, you can use a web app to further investigate lake identification and surface albedo: <https://sleuthyruthie.users.earthengine.app/view/explore-band-reflectances---split-panel>,
<https://sleuthyruthie.users.earthengine.app/view/explore-band-reflectances---lake-mask>
- SUBglacial lakes are under the ice. SUPRAglacial lakes are on top of the ice. But what about ENglacial lakes? They are inside the ice!! Have students read more about this special phenomenon here:
<https://blogs.egu.eu/divisions/cr/2017/03/10/image-of-the-week-hidden-lakes-in-east-antarctica/> or
<https://www.livescience.com/57193-photos-antarctica-meltwater-lake.html>